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EXECUTIVE SUMMARY

Executive Summary

The Reynolds Metals Company (RMC) owns an aluminum reduction facility in Troutdale, Oregon, that historically has produced aluminum from alumina (reduced aluminum ore). RMC and its consultant, CH2M HILL, have performed a series of investigations of groundwater conditions at the facility. Through these investigations, a preliminary conceptual model of the hydrogeology has been developed of the site and its surrounding area. This report describes key elements of the site conceptual model. As work progresses at the site and its surrounding area, the preliminary conceptual model presented in this report is expected to be refined. The work that is discussed in this report was conducted in cooperation with the U.S. Environmental Protection Agency (EPA) Region 10 Response Group and its consultant, Ecology and Environment, Inc.

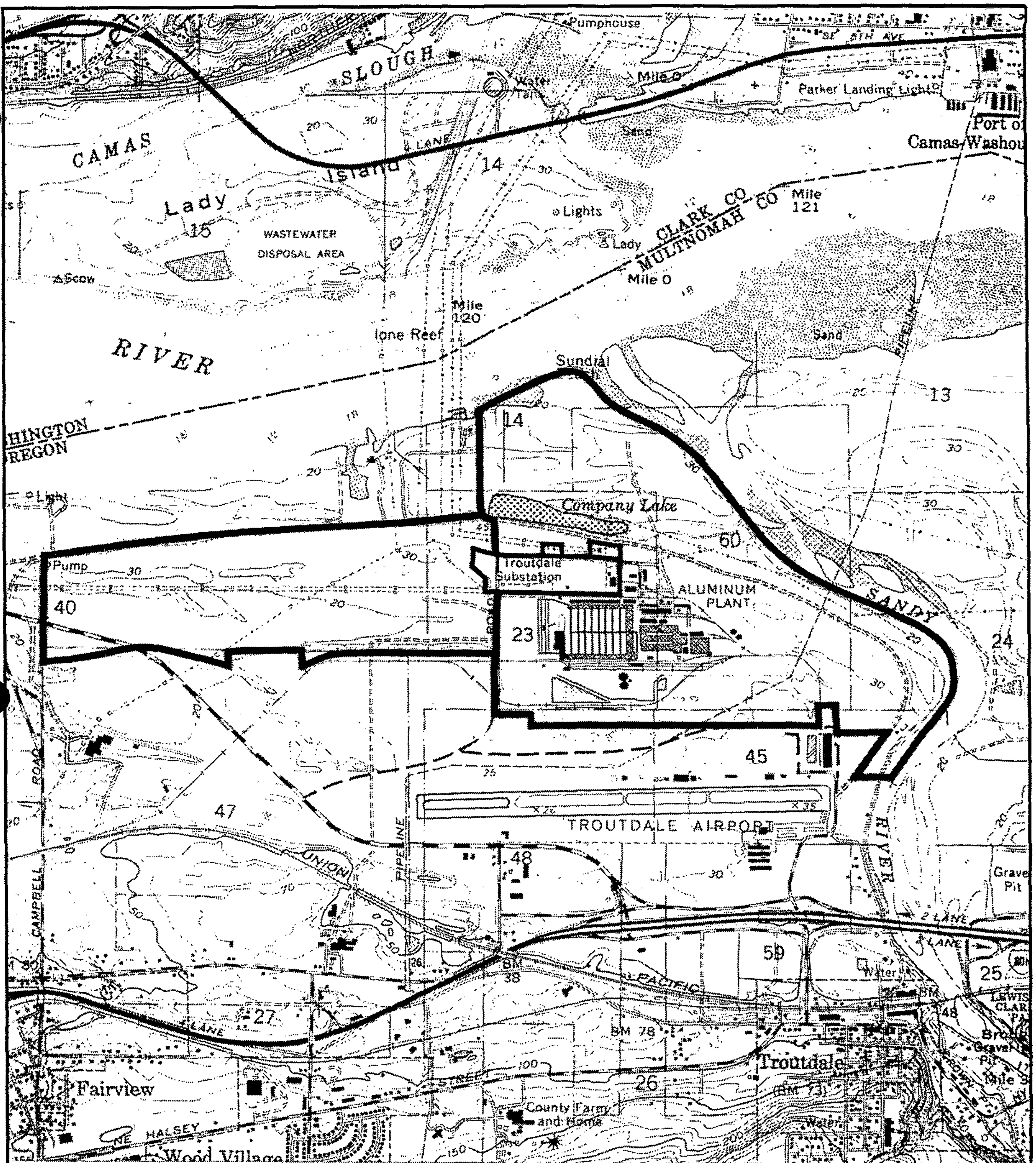
The RMC facility is located in Troutdale, Oregon, east of Portland and north of Interstate Highway 84. The site is located just west of the confluence of the Sandy and Columbia Rivers and abuts the south shore of the Columbia River. The facility consists of an 80.25-acre developed industrial area surrounded by about 715 acres of generally undeveloped land owned by RMC. Figure E-1 is a map showing the site location. Currently, aluminum casting is the only industrial production occurring at the RMC facility. RMC plans to restart aluminum reduction activities at the facility during 1996.

Investigation Activities

This conceptual model is based on the results of field work in the vicinity of the Troutdale facility supplemented by published literature. The field work that has been conducted includes installing 31 shallow (less than 35 feet deep) monitoring wells; geologically logging the subsurface profile penetrated during monitoring well drilling; measuring water levels; analyzing groundwater and surface water samples; and conducting aquifer tests. The literature reviewed for this effort included published agency documents (U.S. Geological Survey, Oregon Department of Geology and Mineral Industries, Oregon Water Resources Department, and Oregon Department of Environmental Quality), agency files such as water well and water rights records, and unpublished consultant reports for the area.

Physical Setting

The RMC Troutdale facility is generally flat and is bordered on the north by the Columbia River, on the south by Graham Road, on the east by the Sandy River, and on the west by Sundial Road. A U.S. Army Corps of Engineers (COE) flood control dike lies within the site boundaries between the developed portion of the site and its northern and eastern edges. Areas north and east of the dike are located within the 100-year floodplain of the adjacent rivers. The major buildings in the developed portion of the site include five potlines, the casthouse, the bakehouse, the carbon plant, and the wastewater treatment system. The



N

0 1000 2000

SCALE IN FEET

LEGEND

APPROXIMATE PROPERTY BOUNDARY

Figure E-1
VICINITY MAP
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
CONCEPTUAL HYDROGEOLOGIC MODEL REPORT

CH2M HILL

Bonneville Power Administration (BPA) maintains a substation in the northwestern portion of the site. Company Lake and East Lake occupy an abandoned channel of the Sandy River north of the COE dike. The south wetlands lie south of the developed portion of the site. Figure E-2 is a map showing site features.

The climate in the vicinity of the RMC Troutdale facility is mild temperate, with an average precipitation of 37 inches per year. Rainfall is seasonal: the majority of rain occurs from November to February. During July, August, and September, the site commonly receives less than one inch of rain per month.

Hydrogeology

Geologic Units

The geologic units in the Portland Basin, from youngest to oldest, include:

- Alluvium
- Flood deposits
- Troutdale Formation
- Interfingered Sandy River Mudstone and Troutdale Formation
- Columbia River Basalt Group (CRBG) and Older Rocks

These units include sandy and silty floodplain deposits of the Columbia and Sandy Rivers (alluvium), glacial flood deposits of sand, gravel, and silt (flood deposits and Troutdale Formation), and fine-grained sand and silt deposited in a lake environment (Sandy River Mudstone). The CRBG and Older Rocks include continental flood basalt, basalt flows from local eruptive centers, and sedimentary rocks deposited in a shallow marine environment.

Hydrogeologic Units

The hydrogeology in the east Portland area has been characterized by several researchers because of the presence of important aquifers (the Columbia South Shore Wellfield) used as a backup water source by the City of Portland and because some of those aquifers have been contaminated by industries located west of the RMC facility. The hydrogeology of the RMC facility, however, differs from that to the west because of a localized erosional/depositional system in the vicinity of the Sandy River-Columbia River confluence. For example, hydrogeologic units referred to elsewhere in the east Portland area as Confining Unit 1, Confining Unit 2, the Troutdale Sandstone Aquifer, and the Troutdale Gravel Aquifer are absent beneath the RMC facility. Instead, the surface of the RMC facility is underlain by as much as 250 feet of a zone referred to as the Unconsolidated Sedimentary Aquifer (USA). A key zone tapped by Portland's Columbia South Shore Wellfield, known as the Blue Lake Aquifer, appears to end about one mile west of the RMC facility but is probably in hydraulic connection with the upper portion of the USA that lies beneath the RMC facility. The top of the Sand and Gravel Aquifer underlies the USA beneath the RMC facility.

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13-Mar-1996

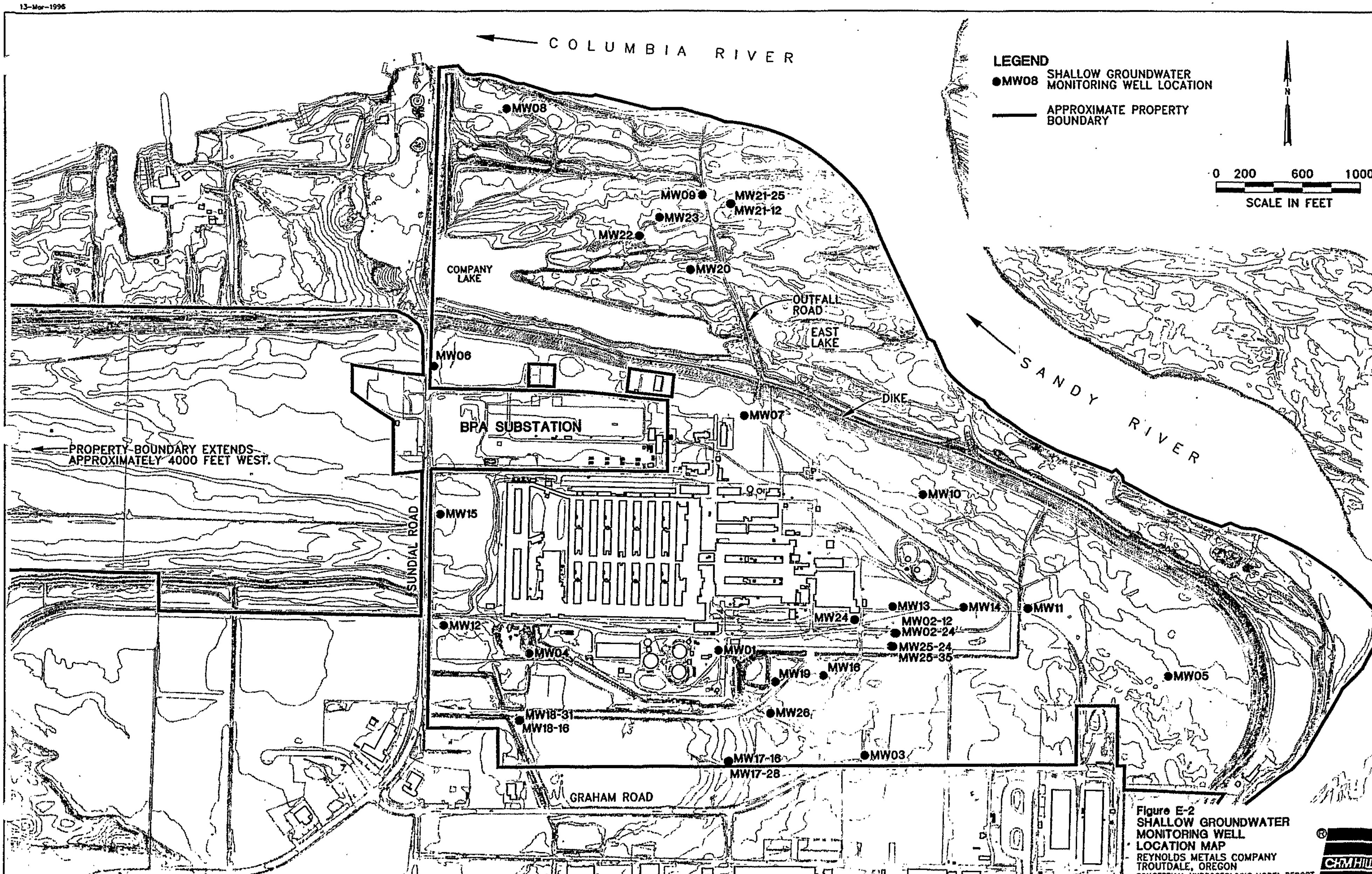

Figure E-2
SHALLOW GROUNDWATER MONITORING WELL LOCATION MAP
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
CONCEPTUAL HYDROGEOLOGIC MODEL REPORT

CH2M HILL

9293SG34.DWG

The driller's geologic log from the deepest RMC production well (PW10) identifies a hard shale zone at about 550 feet below ground surface. It is probable that the "shale" referred to on the log is the top of platy basalt beneath the facility and represents the top of either the CRBG or Older Rocks. The depth to Older Rocks is variable: south of the RMC facility, at the Troutdale Airport, Older Rocks were encountered at a depth of 450 feet; north of the site, Older Rocks are exposed at the surface as an island in the Columbia River (Ione Reef).

The shallow sediments penetrated by RMC monitoring wells to a depth of 35 feet are heterogeneous floodplain deposits of the Sandy and Columbia Rivers. North of the COE dike, shallow sediments are generally coarser (primarily sand) than the silt and sand observed south of the dike. Across the site from east to west, the shallow sediments vary in grain size from sand to silt in no particular pattern, consistent with a fluvial (stream) depositional environment.

Surface Water Hydrology

Surface Water Features

The main surface water features (see Figure E-3) in the RMC site vicinity are the following:

- The Columbia River, flowing east to west along the northern site boundary
- The Sandy River, flowing southeast to northwest along the eastern site boundary
- Company Lake and East Lake, each of which currently occupies separate portions of an abandoned Sandy River channel north of the COE dike. Company Lake is a part of RMC's wastewater treatment system that discharges to the Columbia River (under a National Pollutant Discharge Elimination System discharge permit)
- Salmon Creek, a dredged and controlled stream that enters the site from the south and exits across the western property boundary
- The South Ditch, which was constructed in 1964 and collects groundwater, process water, and stormwater in the developed part of the site and conveys it northward to Company Lake
- The south wetlands, which formerly was used as a process wastewater sedimentation area receiving solids from plant operations until 1964. After the South Ditch was constructed to carry wastewater to Company Lake, the south wetlands contained water primarily during periods of heavy rainfall (generally between November and February). The south wetlands is drained by the West Drainage, a manmade tributary of Salmon Creek.

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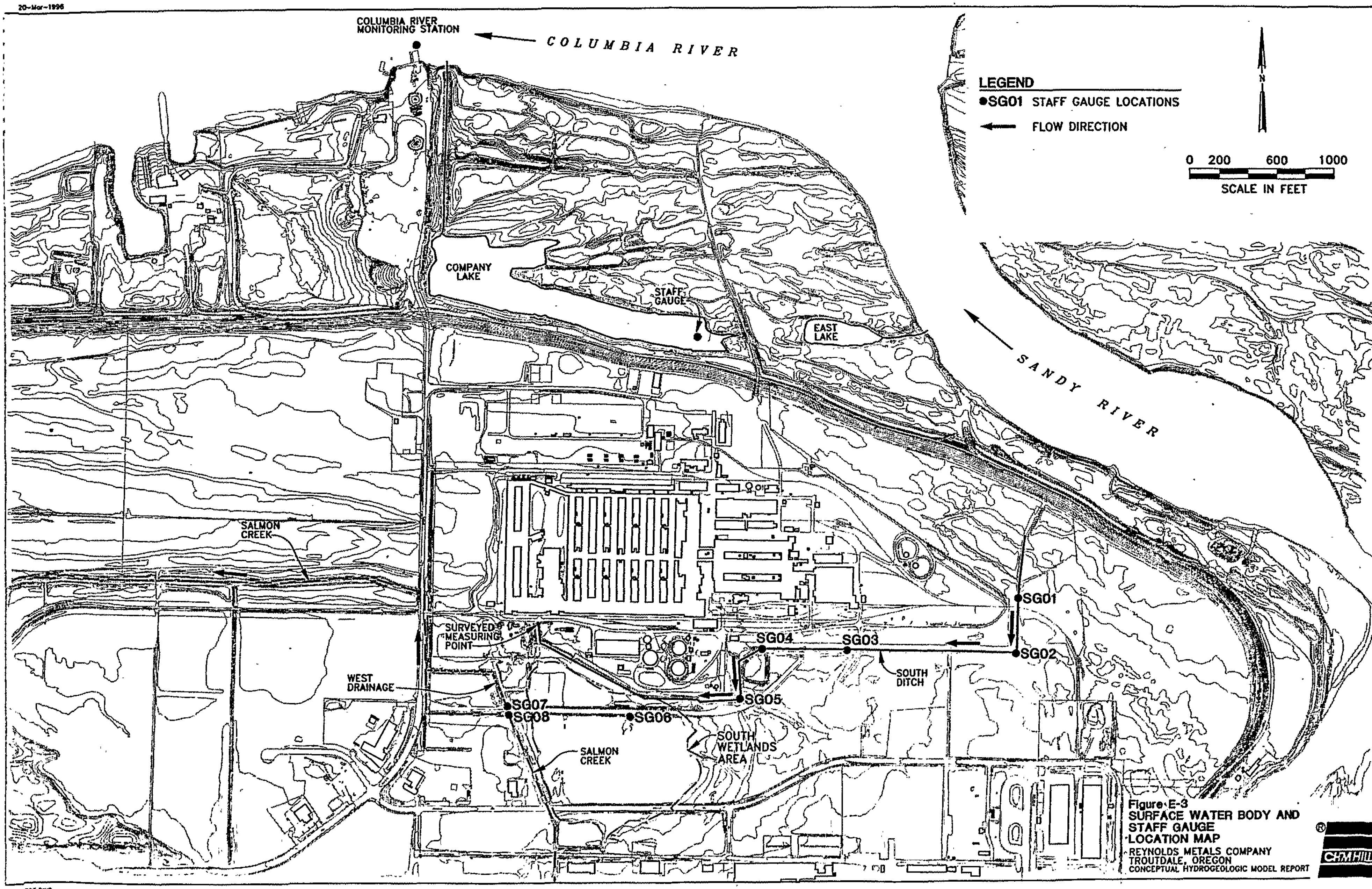

Figure E-3
SURFACE WATER BODY AND STAFF GAUGE LOCATION MAP
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
CONCEPTUAL HYDROGEOLOGIC MODEL REPORT

CH2M HILL

9293SG35.DWG

Surface Water-Groundwater Interaction

The primary surface water influence on groundwater elevations is the Columbia River. The stage of the Columbia River changes in response to runoff, Bonneville Dam releases by COE, and tidal response from the Pacific Ocean (located about 140 miles west of the site). COE dam operations and precipitation events can cause river stage changes of approximately 10 feet (ft). Tides cause twice-daily river stage changes of 2 to 3 ft in the Columbia River. RMC 1994 river stage measurements in the Sandy River and the Columbia River showed that both rivers behave similarly near the site. Groundwater responds to changes in Columbia River levels differently across the site, depending on three main factors:

- Hydraulic conductivity (hydraulic conductivity is proportional to response to river stage changes)
- Proximity to RMC pumping wells (proximity to active production wells is inversely proportional to response to river stage changes)
- Distance from rivers (distance from either the Columbia or the Sandy River is inversely proportional to response to river stage changes)

Because Company Lake receives a fairly constant flow of process water from RMC operations, and because its outlet to the Columbia River is controlled by a weir, Company Lake shows little response to seasonal fluctuations in precipitation or river stage. The degree of hydraulic connection between groundwater and Company Lake is not well known; however, seasonal variations may cause the water table to rise in the winter above the base of the lake at its eastern boundary. Conversely, during the summer months, the water table near Company Lake appears to drop several feet below the base of the lake.

Groundwater in the immediate vicinity of the South Ditch is collected by the ditch and carried to Company Lake during most of the year. During the low-groundwater conditions in the summer, however, the South Ditch may locally have water levels higher than nearby groundwater elevations, causing surface water from the ditch to temporarily recharge groundwater. In its eastern reach, portions of the South Ditch have been observed to go dry during periods of low groundwater levels.

The relationship between shallow groundwater levels and water levels in the south wetlands is currently being evaluated by collecting water level data from newly installed wells near the wetlands.

Groundwater Hydrology

Groundwater Flow Directions

Groundwater is shallow beneath the RMC facility. Depths to groundwater in shallow (less than 35 ft deep) monitoring wells typically vary from 5 to 15 ft. Static depths to groundwater in deeper production wells (generally greater than 200 feet deep) are typically

15 to 30 ft below ground surface, depending on the proximity to pumped RMC production wells.

Shallow groundwater flow patterns at the RMC site are complex because of the influence of surface water features and because of the effect of variable hydraulic conductivity across the site (Figures E-4 and E-5). In general, groundwater flows from south to north across the site and discharges to the Columbia River. Locally, however, the water table forms a series of mounds, ridges, and troughs. It is apparent from Figures E-4 and E-5 that the horizontal hydraulic gradient at the site varies with location and, within a particular area, may vary over time. The horizontal hydraulic gradients estimated from Figures E-4 and E-5 ranges from 0.003 to 0.02 ft/ft.

Groundwater flow in the deep aquifer is not well understood because of limited information. It is likely that deep groundwater converges toward nearby RMC pumping wells.

As with horizontal gradients in the shallow zone, the vertical hydraulic gradient varies both spatially and temporally. It is possible to calculate vertical gradients within the shallow water-bearing zone at five locations where monitoring wells of different depths have been installed next to each other. These vertical gradients vary from an upward gradient of 0.03 ft/ft to a downward gradient of 0.80 ft/ft. In general, vertical hydraulic gradients are directed downward. The vertical gradient between the shallow zone monitored by existing site monitoring wells and the deeper zone tapped by RMC production wells is directed downward because of deep aquifer drawdown induced by pumping from RMC's production wells.

Hydraulic Properties

Hydraulic properties at the RMC facility have been estimated using slug tests and a single-well aquifer test. In addition, a multiple-well aquifer test has been conducted to evaluate aquifer response to pumping rates greater than those likely to occur once the plant resumes aluminum production. Additional aquifer testing and aquifer hydraulic analysis are planned at the RMC site. Future data reports are expected to present an improved understanding of the range and distribution of aquifer characteristics.

Slug Testing

Twenty shallow monitoring wells have been slug tested using compressed nitrogen, a packer, and a data logger/pressure transducer assembly. Hydraulic conductivity ranged from 0.01 ft/day [4.2×10^{-6} centimeters per second (cm/sec)] at MW15 up to 100 ft/day (3.5×10^{-2} cm/sec) at MW09. The wide range of observed hydraulic conductivities is consistent with the conceptual model of a heterogeneous shallow aquifer composed of sediments deposited in a variable fluvial environment.

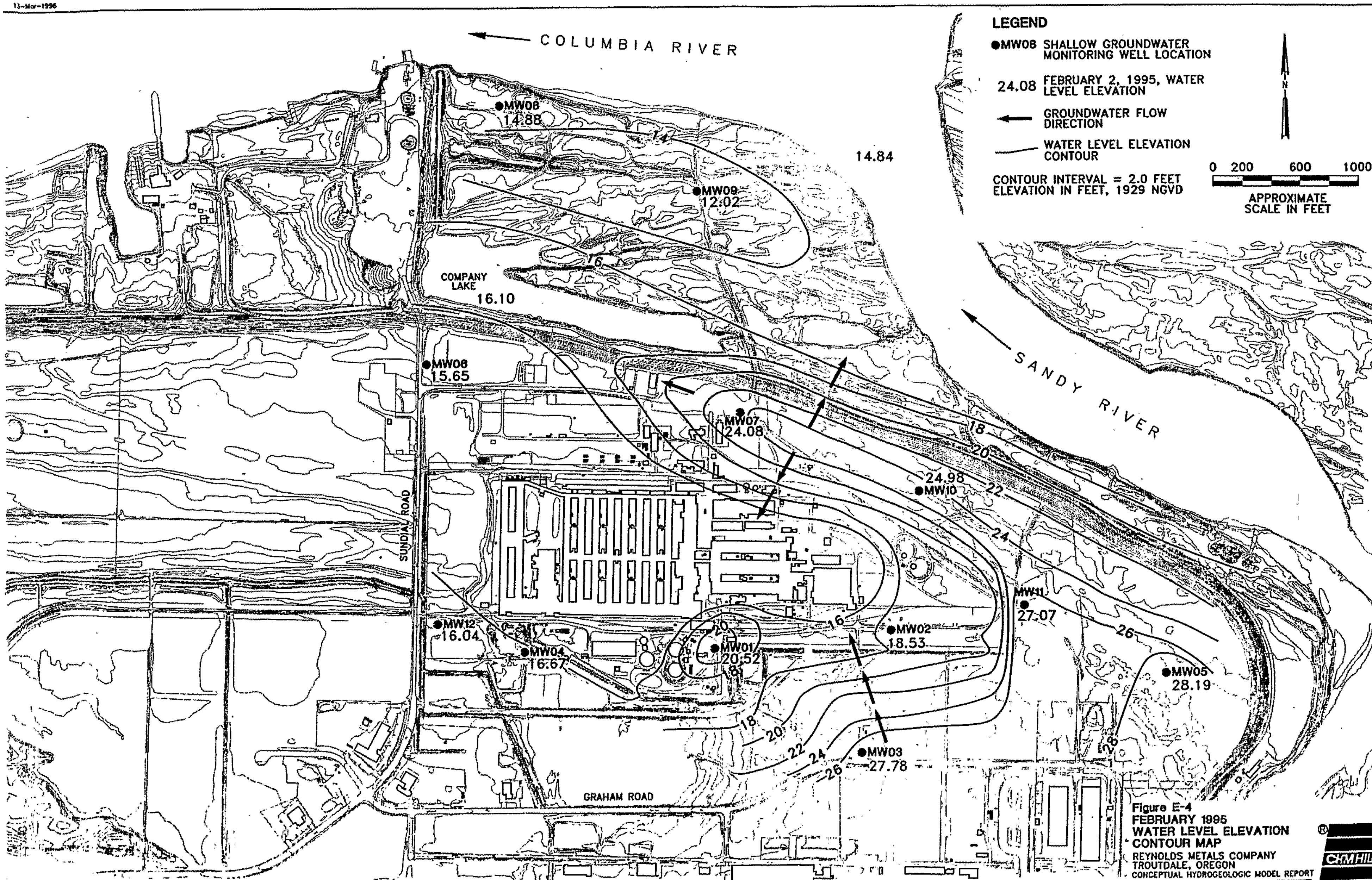

Figure E-4
FEBRUARY 1995
WATER LEVEL ELEVATION
CONTOUR MAP
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
CONCEPTUAL HYDROGEOLOGIC MODEL REPORT

CH2MHILL

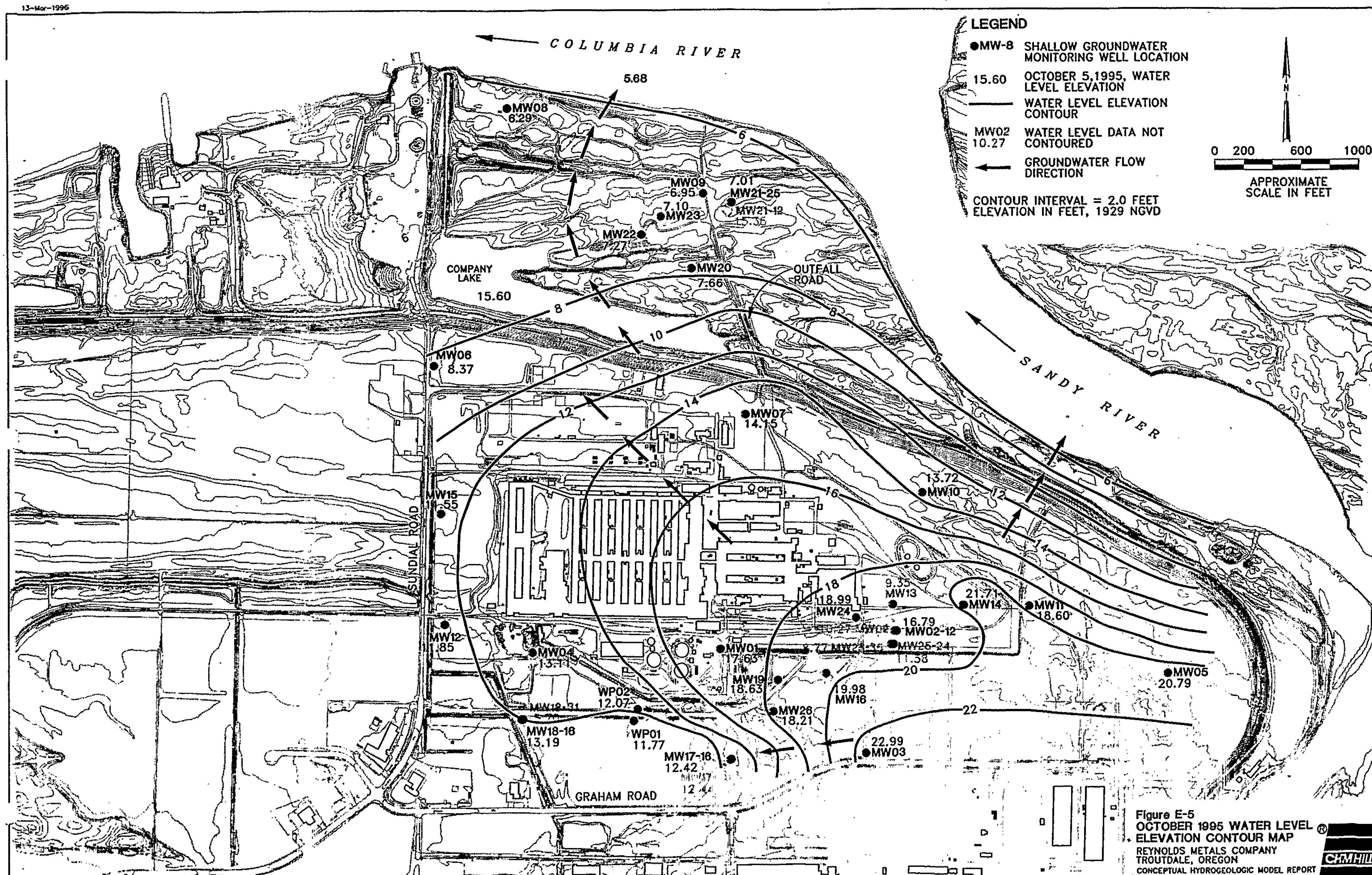

Figure E-5
OCTOBER 1995 WATER LEVEL ELEVATION CONTOUR MAP
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
CONCEPTUAL HYDROGEOLOGIC MODEL REPORT
CH2M HILL

Single-Well Aquifer Testing

A single-well aquifer test was conducted at RMC's Fairview Farms Well No. 4 (FF04) to provide an estimate of deep zone aquifer transmissivity and to help evaluate response to deep zone pumping west of the facility. Well FF04 was pumped at an average discharge of 990 gallons per minute (gpm) for 455 minutes, at which time mechanical difficulties caused the test to end prematurely. Using time-drawdown and time-recovery data from FF04, FF06, PW16, and PW17, transmissivity values were calculated to range from 23,000 to 79,000 square feet per day (ft^2/day) [2,100 to 7,300 square meters per day (m^2/day)], with an average for the observation wells (FF06, PW16, and PW17) of 46,000 ft^2/day (4,300 m^2/day). Aquifer storage coefficients ranged from 0.002 to 0.004, indicating the presence of leaky-confined conditions.

Two shallow monitoring wells (MW06 and MW12) near the west edge of the site were monitored during the test. MW06 showed an estimated drawdown of 0.34 ft to pumping at FF04, which is the same order of magnitude of drawdown observed in deep wells located a similar distance from FF04, indicating a hydraulic connection between the shallow zone and deep aquifer in this area. MW12, on the other hand, showed no discernible response to pumping from FF04. On the basis of these observations, it is apparent that the degree of hydraulic connection between shallow and deep groundwater varies across the western portion of the site.

Multiple-Well Aquifer Testing

A multiple-well aquifer test was conducted by pumping four RMC production wells (PW03, PW07, PW08, and PW10) at a total discharge rate of between 2,800 and 2,900 gpm for 58.5 hours. The aquifer test was prematurely terminated because of a precipitation event that caused water in the South Ditch to nearly overflow into the south wetlands. During the aquifer test, water levels were monitored in 31 onsite shallow groundwater monitoring wells, 11 onsite deep-zone production wells, and two offsite deep-zone irrigation wells. Water levels were also measured in four offsite wells several miles southwest of the site, as well as in City of Portland production wells.

Drawdown estimates in shallow monitoring wells ranged from zero to 1.3 ft. The response to deep aquifer pumping observed in onsite shallow monitoring wells indicates that the extent and magnitude of drawdown resulting from the multiple-well aquifer test are variable, supporting the conceptual model of a heterogeneous aquifer system composed of laterally discontinuous lenses or beds of varying hydraulic conductivity. In general, shallow monitoring wells with minimum depths of 25 ft exhibited drawdown. The presence of response in wells shallower than 25 ft is more variable, indicating that the presence of low-permeability sediments in the upper 25 ft of the aquifer influences shallow zone response to pumping in the deeper portion of the aquifer.

Analysis of estimated drawdown in deep-zone wells extending from the RMC site west toward the City of Portland Columbia South Shore Wellfield indicates that hydraulic influence to the multiple-well aquifer test was observed as far west as well FF06, approximately 1 mile west of the pumping center at the site. Drawdown was not observed at the City of Portland production wells located near the eastern end of the Columbia South Shore Wellfield. On the basis of a plot of estimated drawdown versus distance from the central portion of the plant, the response to pumping at the RMC facility was estimated to have extended approximately 8,000 ft west of the facility. This radius of influence was estimated for the area west of the facility only. The actual distance from the facility that drawdown could be observed will vary with direction, depending on the following variables:

- The magnitude and direction of the background horizontal hydraulic gradient and flow direction
- Changes in aquifer thickness or permeability
- Changes in the degree of hydraulic connection with nearby surface water bodies
- Increased drawdown, or drawdown in other areas, may have been observed if the aquifer test pumping period had been greater
- The amount of water contributed by leakage from overlying or underlying zones relative to the pumping rate

The hydraulic influence of pumping, sometimes referred to as the radius of influence, should not be confused with the capture zone of a pumping well. A radius of influence is an idealized concept that is defined as the area within which response to pumping can be measured. A capture zone, by comparison, is defined as the area around a pumping well that actually contributes water to the well. If an aquifer had no flow within it (that is, no hydraulic gradient), the capture zone would be equivalent to the radius of influence. Because aquifers in nature have a hydraulic gradient, a capture zone's width is less than the radius of influence for a given set of hydraulic conditions and pumping rate. Therefore, drawdown can be felt outside the capture zone of a pumping well, and the existence of drawdown at a particular observation point does not necessarily mean that groundwater can flow from the observation point to the pumping well.

Groundwater Flow Velocity Estimates

Horizontal groundwater flow velocity estimates in the shallow aquifer near the RMC facility range from 0.001 ft/day to 1.2 ft/day (0.0003 to 0.366 m/day). These velocity estimates are based on ranges of horizontal hydraulic gradients obtained from groundwater elevation contour maps, an estimated effective porosity of 25 percent, and estimated horizontal hydraulic conductivity values obtained from slug testing in shallow groundwater monitoring wells. The wide range of groundwater velocity estimates is consistent with the fluvial depositional environment.

Water Quality

This report discusses the general chemistry of groundwater and surface water at the RMC facility. The distribution and concentration of constituents of concern (generally fluoride, cyanide, and polynuclear aromatic hydrocarbons) are described in other reports.

On the basis of general chemical analysis of water samples from these sources, the following groupings can be made:

- Shallow "unaffected" groundwater, which is groundwater from wells that are considered to show little or no effect from past practices at the site
- Shallow "affected" groundwater, which is groundwater from wells that clearly show water effects from past practices
- Deep groundwater from production wells
- Surface water

Shallow unaffected groundwater (examples include MW03, MW06, M10, and MW20) has a similar chemistry regardless of location. This water is a sodium bicarbonate type, with the concentration of sodium+potassium ranging from less than 1.0 to 4 milliequivalents per liter (meq/L) and bicarbonate ranging from 1.0 to 3.5 meq/L.

Shallow groundwater that appears to have been affected by past practices (examples include MW04, MW11, MW21-12, and MW26) contains higher total dissolved solids than unaffected groundwater. Shallow affected groundwater is also a sodium bicarbonate type, but concentrations of sodium+potassion range from 5 to 27 meq/L, and concentrations of bicarbonate range from 3 to 19 meq/L. Despite their various locations across the site, the affected monitoring wells exhibit similar general water quality parameters regardless of the source area with which they are associated.

Deep groundwater is similar to shallow unaffected groundwater, with the exception of PW10. This well is the deepest of RMC's production wells (625 ft) and is believed to be affected by chloride-enriched water associated with deep marine sedimentary rocks.

Surface water samples from Company Lake, the South Ditch, and the Columbia River outfall were analyzed for cations, but not anions. In general, surface water had slightly more calcium and magnesium than did groundwater, and cation concentrations were approximately one order of magnitude lower. Company Lake cation proportions were most similar to PW18, and Salmon Creek cation proportions were most similar to FF04 (and shallow well MW15). The Columbia River outfall had higher calcium+magnesium and sodium+potassium concentrations than other surface water at the site.

Local Water Use

Groundwater and surface water are used for water supply in the site vicinity. Oregon Water Resources Department (OWRD) records indicate that 38 wells are on file within a one-mile radius of the site; however, two of these wells are temporarily abandoned and one is a test well. The other wells are listed as having domestic, municipal supply, irrigation, or industrial uses. Reported well depths ranged from 36 to 1,060 ft, and reported yields ranged from 12 to 1,500 gpm. Most wells are screened within the USA. The nearest wells to the RMC facility, not considering RMC's own production wells, are two wells at the BPA substation adjacent to the north side of the plant, an industrial well at Sundial Marine Tug and Barge, and a former domestic well at Gresham Sand and Gravel that is not used for drinking water. These latter two wells are both located northwest, and possibly downgradient, of the site. RMC uses its deep production wells to supply both process water and drinking water for the facility. The OWRD listed 21 groundwater use permits for the area; 20 of these are owned by RMC, and the other permit owner is BPA.

The OWRD maintains files for surface water use permits on the Sandy River and the south shore of the Columbia River. The Washington Department of Ecology has responsibility for surface water use permits on the north shore of the Columbia River. No Sandy River permits were on file for the site vicinity, and a total of 17 surface water permits were on file for the area along the Columbia River between the RMC facility and downstream to the confluence with the Willamette River (approximately 19 miles northwest of the site).

SECTION 1

INTRODUCTION

Section 1
Introduction

This report describes the preliminary conceptual hydrogeologic model developed from work conducted at the Reynolds Metals Company (RMC) facility in Troutdale, Oregon. The work was conducted as part of the 1994 and 1995 environmental investigations at the RMC facility, which were completed in cooperation with the U.S. Environmental Protection Agency (EPA) Region 10 Response Group. Investigations at the RMC site were conducted in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

The RMC facility is situated north of Interstate 84, approximately 1.25 miles north of the City of Troutdale, Oregon, and about 2 miles southeast of Camas, Washington (see Figure 1-1). The site is located within Sections 14 and 22 through 24 of Township 1 North, Range 3 East, Willamette Meridian, Multnomah County. The Columbia River forms the site's northern border, and the Sandy River forms its eastern border. The site consists primarily of an 80.25-acre industrial area surrounded by approximately 715 mostly undeveloped acres.

1.1 Purpose and Scope

The purpose of this report is to present a conceptual model of the occurrence, movement, and general quality of groundwater in the vicinity of the RMC facility. An understanding of local groundwater flow directions, areas of groundwater recharge and discharge, and general quality will assist in evaluating (a) how groundwater interacts with surface water and (b) the potential pathways and receptors of constituents in shallow groundwater onsite. Regional hydrogeology and groundwater hydrology are described to provide a context for interpreting site conditions. The local water use survey (discussed in Section 7) provides a summary of groundwater use within a one-mile radius of the RMC facility and identifies surface water and groundwater use permits. The purpose of the water survey is to provide background information on water users in the site vicinity.

This document includes descriptions of both the regional and site-specific hydrogeologic settings for the RMC facility area. Sources of information used to produce this report include:

- Readily available literature
- Field investigation results
- Driller's logs for area wells
- Interviews with state agency and local city or county personnel (to supplement information on area water use and hydrogeologic information obtained from the literature review)

RMC ConHydModelRpt, Fig 1-1, 2/96

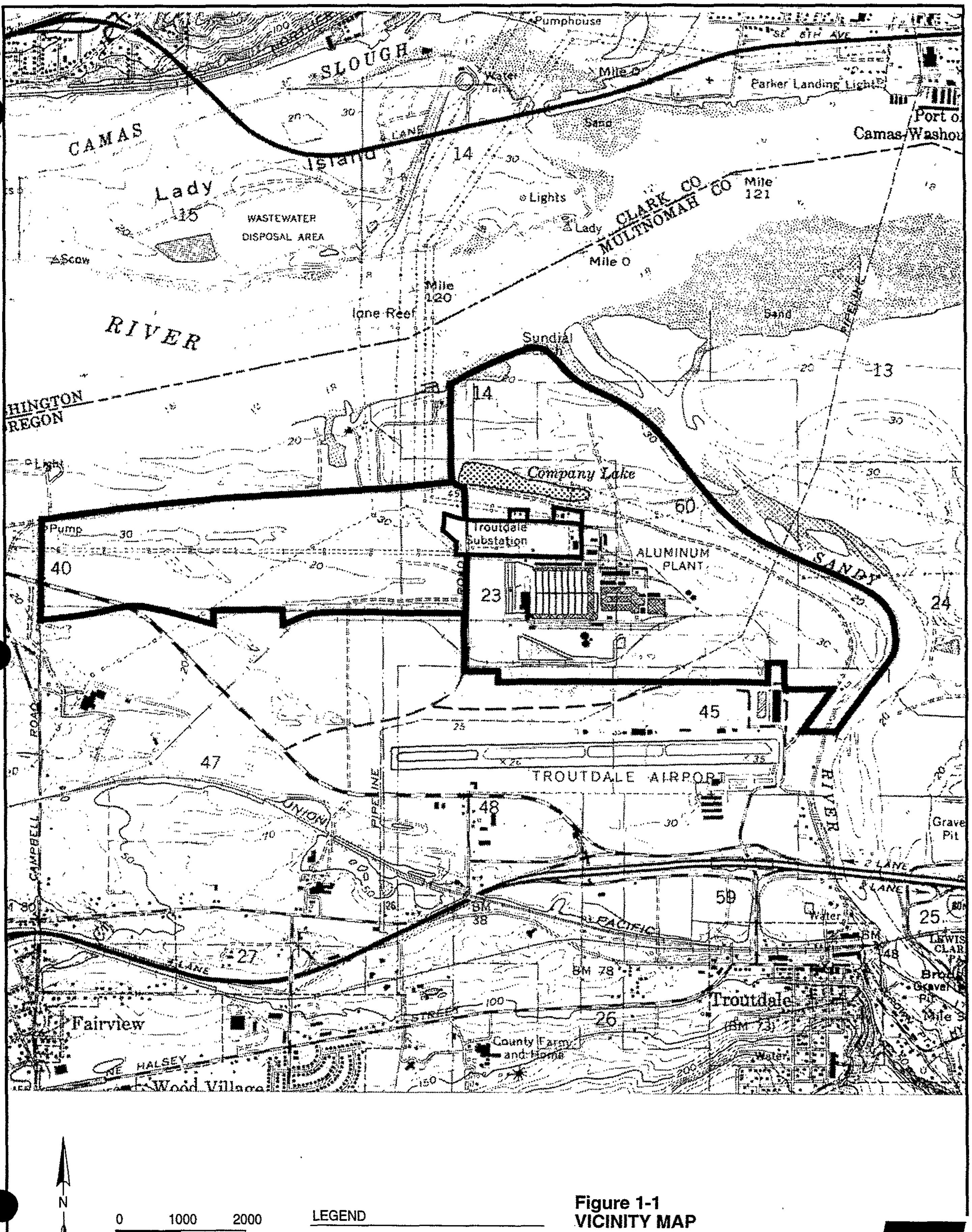

Figure 1-1
VICINITY MAP
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
CONCEPTUAL HYDROGEOLOGIC MODEL REPORT

CH2M HILL

This report was prepared early in the investigation process at the RMC facility, before completion of the remedial investigation (RI). The report will be revised or appended as needed after additional data are collected and/or as understanding of the site hydrogeology improves.

1.2 Methods of Investigation

1.2.1 Literature Review

A literature review was conducted to develop an understanding of geography, climate, geology, and hydrology for the study area. Reports used in this review are listed in Table 1-1 and include U.S. Geological Survey (USGS), Oregon Department of Environmental Quality (DEQ), and Oregon Water Resources Department (OWRD) documents, as well as consultant reports.

1.2.2 Field Methods

Field investigations at the facility have been conducted primarily to investigate the risk associated with—or the potential for releases to groundwater from—identified onsite source areas. Because most field investigations have included the installation of shallow [up to 35 feet below ground surface (bgs)] groundwater monitoring wells, sufficient data to produce a preliminary assessment of shallow groundwater conditions (in the upper 20 to 30 feet of the aquifer) have been collected. Table 1-2 provides a groundwater monitoring well construction summary, Figure 1-2 shows the locations of shallow groundwater monitoring wells at the RMC site, and Appendix A contains monitoring well construction diagrams. Figure 1-3 shows the location of RMC production wells.

Components of the field investigations that help characterize groundwater include an evaluation of shallow subsurface geology, depth to groundwater, and hydraulic properties (transmissivity, hydraulic conductivity, vertical and horizontal hydraulic gradients, and groundwater flow directions). Through September 1995, 31 permanent shallow groundwater monitoring wells and 11 temporary shallow monitoring wells (9 have been removed) had been installed at the site. These wells have been used to gather the following data:

- Soil classification encountered during well drilling
- Water level measurements
- Estimates of hydraulic coefficients from aquifer testing results
- General groundwater chemistry results

In addition to the monitoring wells, water levels were measured in some of the onsite production wells (screened below 140 feet bgs), as well as in onsite and nearby surface water features. These data were used to evaluate vertical gradients and to assess the interaction between groundwater and surface water. Groundwater has been sampled for a variety of constituents as part of the RMC site characterization and the removal site assessment (CH2M HILL, 1995a). Sample analysis generally included:

Table 1-1
Summary of Literature Reviewed
Reynolds Metals Company
Troutdale, Oregon

Author	Date	Investigation Area	Title (Agency)
Trimble, D.E.	1963	Portland	*Geology of the Portland, Oregon and Adjacent Areas* (U.S.G.S. Bulletin 1119. 119 p.)
Mundorff, M.J.	1964	Clark County	*Geology and Ground-water Conditions of Clark County, Washington, with a Major Alluvial Aquifer along the Columbia River.* (U.S.G.S. WSP 1600. 268. p.)
Hogenson, G.M. and B. L. Foxworthy	1965	East Portland	*Ground water in the East Portland Area.* (U.S.G.S. WSP 1793. 78. p.)
Willis, R.F.	1977	Portland Well Field	Ground Water Exploratory Program (Bureau of Water Works, Portland, Oregon. 284 p.)
Willis, R.F.	1978	Portland Well Field	*Pilot Well Study.* (Bureau of Water Works, Portland, Oregon. 150 p.)
Hoffstetter, W.H.	1984	Portland Well Field	*Geology of the Portland Well Field.* (Oregon Geology, Oregon DOGAMI, v. 46, no. 6. p 63- 67)
Noble, J.B. and C.Ellis	1980	Vancouver	*City of Vancouver Ground Water Source and Use Study - Vol. I Summary.* (Report Prepared for the City of Vancouver by: Robinson, Noble, and Carr, Inc., Tacoma, Wash., 42 p.)
Carr, J.R. and Associates	1985	South Clark County	*Ground Water Management and Development Plan.* (Report Prepared for Clark Co. Public Utility District by: J.R. Carr and Associates, Gig Harbor, WA.)
Hartford, S.V. and W.D. McFarland	1989	Portland Well Field	*Lithology, Thickness, and Extent of Hydrogeologic Units Underlying the East Portland Area, Oregon.* (U.S.G.S. WRI Report 88-4110, 23 p.)
Parametrix	1991	East Multnomah Co.	*East Multnomah County Database and Model, Geologic Interpretation- Detailed Study Area.* (Prepared for Oregon DEQ)
James N. Bet and Malia L. Rosner (Landau Associates)	1993	East Multnomah Co.	*Geology near Blue Lake County Park, Eastern Multnomah County, Oregon.* (Oregon Geology, Vol. 55)
Swanson, R.D., W.D. McFarland, J.B. Gonthier, and J.M. Wilkinson	1993	Portland Basin	*A Description of Hydrogeologic Units in the Portland Basin, Oregon and Washington.* (U.S.G.S. WRI Report 90-4196, 60 p.)

Notes:
U.S.G.S. = United States Geological Survey.
WSP = Water-Supply Paper.
DOGAMI = Department of Geology and Mineral Industries.
WRI = Water Resources Investigations

Table 1-2
Groundwater Monitoring Well Construction Summary
Reynolds Metals Company
Troutdale, Oregon

Well ID	Installation Date	Depth *(a)*	Casing Diameter *(b)*	Borehole Diameter	Screened Length (feet)	Screened Interval *(a)*	Top of Filter Pack *(a)*	MPE *(c)*	GSE *(d)*	Screened Material	Well Location *(e)*
MW01	7/12/94	20	4-inch	12-inch	10	9 to 19	7	28.25	25.2	Sand (SP) Silt (ML)	Wastewater Treatment System
MW02-12 (formerly TMW05) (f)	7/25/95	12.5	2-inch	10-inch	5	7 to 12	6	31.10	28.3	Silt (ML)	Scrapyard
MW02-24 (formerly MW02)	7/11/94	24	4-inch	12-inch	10	14 to 24	12	31.65	28.6	Sand (SP,SM) Silt (ML)	Scrapyard
MW03	7/9/94	18	2-inch	10-inch	8	9 to 17	7	29.69	27.4	Sand (SP,SM)	Background
MW04	7/12/94	20	2-inch	10-inch	10	9 to 19	7	26.91	24.3	Silt (ML) Clay (CL)	South Wetlands
MW05	7/8/94	25	2-inch	10-inch	10	15 to 24.5	12	33.99	31.6	Silt (ML) Sand (SM)	Background
MW06	7/8/94	25	2-inch	10-inch	10	13.5 to 23.5	11	26.81	24.1	Silt (ML) Sand (SP,SM)	Western Plant Boundary
MW07	7/9/94	25	4-inch	12-inch	10	14 to 24	12	28.38	28.7	Sand (SM) Silt (ML)	Parking Lot
MW08	7/7/94	28	2-inch	10-inch	10	17 to 27	14	25.32	22.8	Sand (SP)	North Landfill
MW09	8/4/94	32	2-inch	10-inch	10	20 to 30	18	29.27	27.0	Sand (SP)	North Landfill
MW10	8/5/94	25	4-inch	12-inch	15	8 to 23	7	30.28	27.9	Silt (ML)	Northeast Plant Boundary
MW11	8/5/94	19	2-inch	10-inch	10	7 to 17	6	31.61	29.5	Sand/Silt (SP/ML)	East Potliner
MW12	8/4/94	23	2-inch	10-inch	5	16 to 21	14	22.53	20.2	Sand (SP) Silt (ML)	South Wetlands
MW13	7/12/95	23	2-inch	10-inch	5	17 to 22	15.5	30.88	28.3	Sand/silt (SP,SM) Sand (SP)	Scrapyard
MW14	7/11/95	16	2-inch	10-inch	10	5 to 15	4	30.88	28.3	Silt (ML) Sand/silt (SP,SM)	Scrapyard
MW15	7/13/95	25	2-inch	10-inch	10	13.5 to 23.5	11	22.75	20.9	Silt (ML) Sand/silt (SP,SM)	Western Plant Boundary
MW16	7/13/95	14	2-inch	10-inch	8	5.5 to 13.5	4	28.91	26.7	Sand (SP)	South of North Landfill
MW17-16	7/21/95	17	2-inch	10-inch	5	11 to 16	10	27.13	24.8	Silt/sand (ML)	South Wetlands
MW17-28	7/21/95	28.5	2-inch	10-inch	5	23 to 28	22	27.30	24.8	Sand (SW) Silt (ML)	South Wetlands
MW18-16	7/20/95	16.5	2-inch	10-inch	5	11 to 16	9.5	23.98	21.5	Sand (SW)	South Wetlands
MW18-31	7/20/95	32	2-inch	10-inch	5	26.5 to 31.5	25	23.95	21.5	Silt (ML) Sand/silt (SP,SM)	South Wetlands
MW19	7/21/95	13.5	2-inch	10-inch	5	8 to 13	6.5	27.10	24.8	Sand (SW) Silt (ML)	South Landfill
MW20	9/1/95	26.5	2-inch	10-inch	10	16 to 26	15	28.46	25.8	Sand (SP)	South Landfill
MW21-25 (formerly MW21)	9/5/95	25	2-inch	10-inch	5	19 to 23.5	17	24.6	22.0	Sand (SP)	North Landfill
MW21-12 (formerly TMW07)	9/5/95	12	2-inch	10-inch	5	7 to 11.5	6	24.54	22.4	Silt (ML)	North Landfill
MW22	9/6/95	27	2-inch	10-inch	10	17 to 26.5	15	25.35	22.6	Sand (SP)	North Landfill
MW23 (formerly TMW06)	9/1/95	25	2-inch	10-inch	10	15 to 24.5	14	26.41	24.1	Sand (SP)	North Landfill
MW24 (formerly TMW01)	7/12/95	12.5	2-inch	10-inch	5	5 to 10	4	30.13	27.3	Sand/silt (SP,SM) Sand (SP)	Scrapyard
MW25-24 (formerly TMW02)	7/12/95	24 Backfilled from 30 ft	2-inch	10-inch	10	13 to 23	11	31.14	28.5	Silt (ML) Silty sand (SM)	Scrapyard
MW25-35 (formerly TMW04)	7/24/95	35.5	2-inch	10-inch	5	30 to 35	29	30.89	28.4	Sand (SW,SP)	Scrapyard
MW26 (formerly TMW03)	7/24/95	12.5	2-inch	10-inch	5	7 to 12	6	26.26	23.9	Sand (SP)	South Landfill

Table 1-2
Groundwater Monitoring Well Construction Summary
Reynolds Metals Company
Troutdale, Oregon

Well ID	Installation Date	Depth *(a)*	Casing Diameter *(b)*	Borehole Diameter	Screened Length (feet)	Screened Interval *(a)*	Top of Filter Pack *(a)*	MPE *(c)*	GSE *(d)*	Screened Material	Well Location *(e)*
Fairview Farms **Well No. 4**	1943 **Well use:** Irrigation	281	**24"** from 0 to 55 ft.; **12"** from 55 to 230 ft. & **8"** from 209 to 281 ft.	Not Known	13	237 to 250	Not Known	18.7	19.1	Sand & gravel	~ 1,300 ft west of Sundial Rd
Fairview Farms **Well No. 6**	1950 **Well use:** Irrigation	200	**18"** from 0 to 140 ft.; **12"** from 119 to 200 ft.	Not Known	81	119 to 200	Not Known	20.85	20.6	Sand & gravel	~ 2,800 ft west of Sundial Rd

Notes:

(a) Feet below ground surface
(b) Monitoring well casing and screen constructed with flush-threaded Schedule 40 PVC with 0.010-inch machine-slotted well screen. Production wells constructed with steel casing.
(c) MPE = Measuring point elevation, feet, NGVD 1929.
(d) GSE = Ground surface elevation, feet, NGVD 1929.
(e) Refer to Figure 1-2 for well locations.
(f) TMW = Originated as temporary monitoring wells then converted to permanent status.

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20-Mar-1996

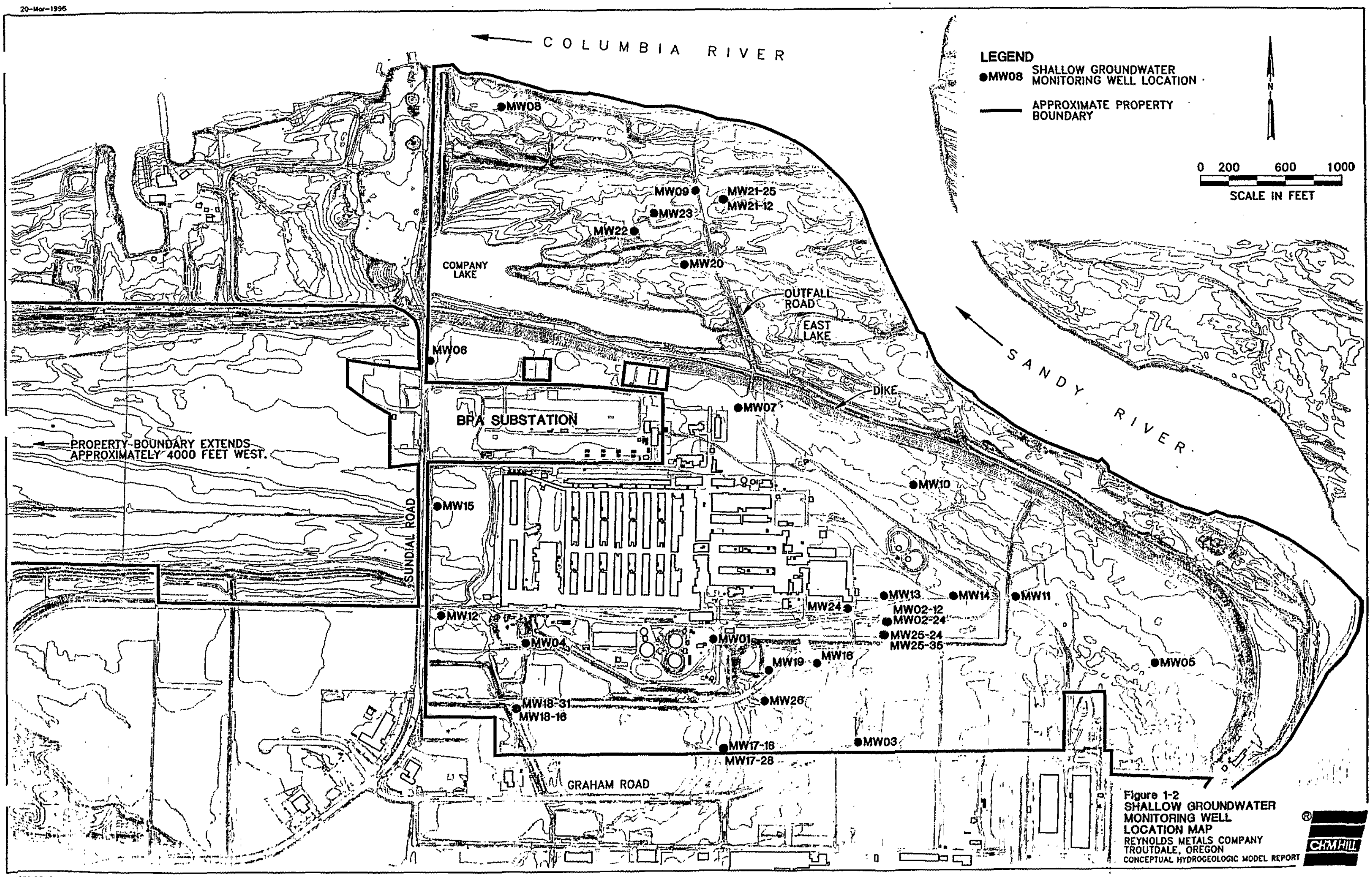

Figure 1-2
SHALLOW GROUNDWATER MONITORING WELL LOCATION MAP
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
CONCEPTUAL HYDROGEOLOGIC MODEL REPORT

9293SG18.DWG

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20-MAR-1996

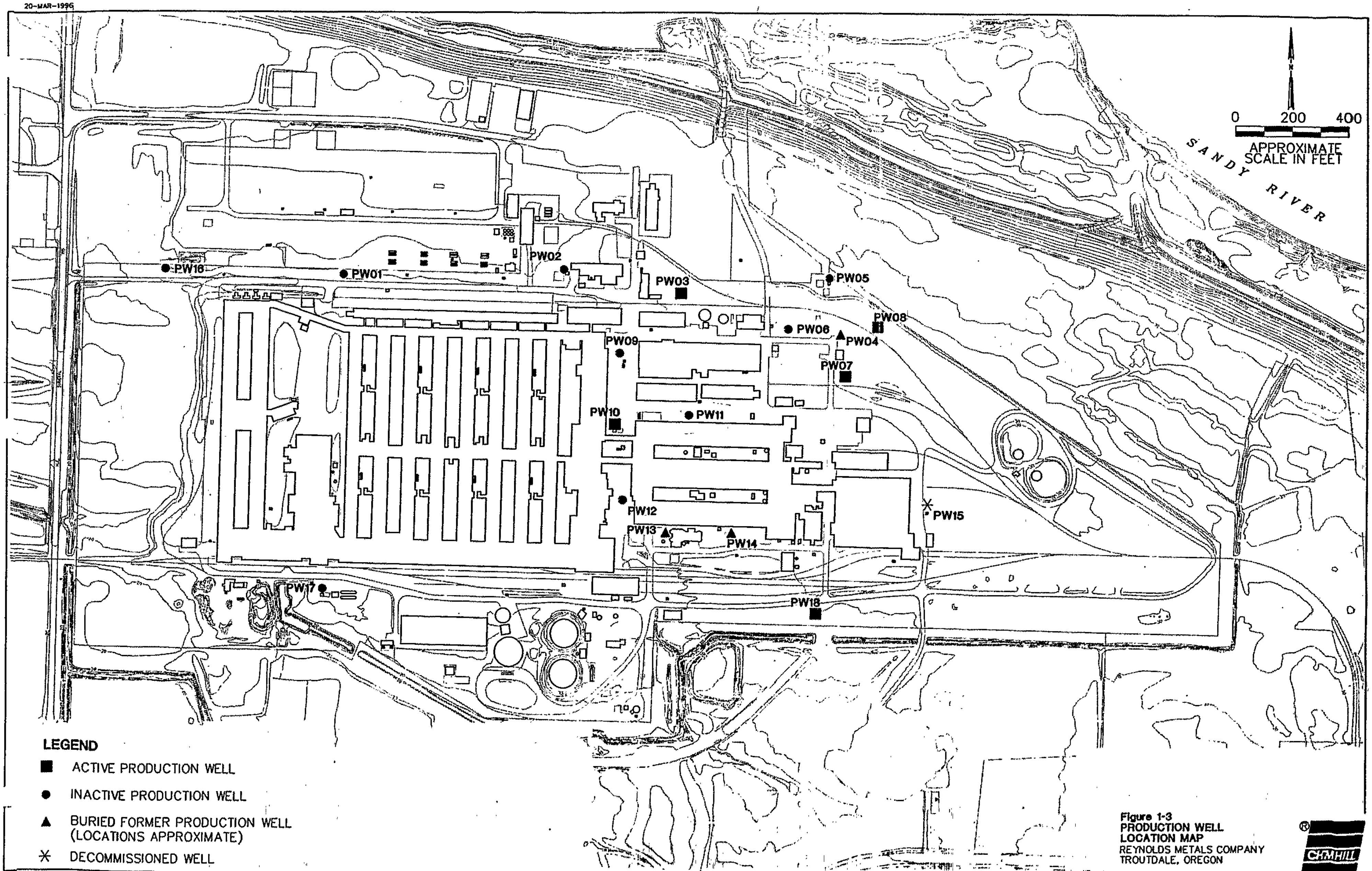

Figure 1-3
PRODUCTION WELL LOCATION MAP
REYNOLDS METALS COMPANY
TROUTDALE, OREGON

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- Volatile organic compounds
- Semivolatile organic compounds
- Total and dissolved metals
- Polychlorinated biphenyls (PCBs)
- Fluoride
- Cyanide (total and amenable to chlorination)
- General chemistry constituents

RMC has been conducting a quarterly groundwater monitoring program, in cooperation with EPA, at the RMC facility since summer 1994. With the exception of the general chemistry analysis, the analytical results from the quarterly groundwater monitoring program are not included in this report. The purpose of the groundwater monitoring program is to assess changes in constituent concentrations in groundwater that may occur over time.

The results of the general chemistry analyses are discussed in Section 6 of this report. The results of the chemical analyses, which focused on constituents related to source areas or impacts, are presented in the following documents:

- *Removal Site Assessment Report* (CH2M HILL, 1995a)
- *Quarterly Groundwater Monitoring Report No. 1* (CH2M HILL, 1995b)
- *Quarterly Groundwater Monitoring Report No. 2* (CH2M HILL, 1995c)
- *Quarterly Groundwater Monitoring Report No. 3* (CH2M HILL, 1995d)
- *Annual Groundwater Monitoring Report: August 1994-August 1995* (CH2M HILL, 1995e)

1.2.3 Well Inventory Survey

Water well reports for wells located within a one-mile radius of the RMC facility were collected from OWRD in Salem, Oregon. The water well log search included the following area: T1N, R3E, Sections 14, 22, 23, 24, 25, 26, and 27 in East Multnomah County, Oregon. Where possible, well locations were field verified. Nearby homes and businesses were visited to identify additional wells within the area of interest.

1.2.4 Groundwater and Surface Water Rights Survey

Surface water use permits for the Sandy River from Interstate 84 (south) to the confluence with the Columbia River, and for the Columbia River from river mile 120.5 (east) to river mile 101 (west), were requested from OWRD. In addition, groundwater use permits were requested for T1N, R3E, Sections 14, 15, 22, 23, 24, 25, 26, and 27.

1.3 Report Organization

This report is organized in the following manner:

Section 1: Introduction. Describes the purpose and scope of this report.

Section 2: Physical Setting. Summarizes topography and climate conditions for the area.

Section 3: Hydrogeology. Describes the current understanding of the regional and site-specific hydrogeologic conditions.

Section 4: Surface Water Hydrology. Summarizes locations of surface water bodies in the area and their potential for interaction with groundwater.

Section 5: Groundwater Hydrology. Summarizes groundwater elevations, hydraulic gradient, and hydraulic property data.

Section 6: Water Quality. Summarizes general chemistry data for shallow groundwater and deeper groundwater in the site vicinity and compares them with surface water, including the Columbia River and Salmon Creek.

Section 7: Local Water Use Survey. Summarizes the water well survey within a one-mile radius of the RMC facility and identifies surface water and groundwater use permits.

Section 8: References.

SECTION 2

PHYSICAL SETTING

Section 2
Physical Setting

2.1 Regional Setting

The study area is located on the south shore of the Columbia River, immediately west of its confluence with the Sandy River. The site is located within the eastern portion of the Portland Basin, a downwarp of pre-Pliocene rocks between the Cascade Range and the Coast Range of Washington and Oregon. The term "Portland Basin" is used to describe the 20-mile-wide and 45-mile-long, northwest-southeast trending, sediment-filled structural depression bounded by the Tualatin Mountains on the west and the Cascade Range on the east, north, and south (Swanson et al., 1993). The RMC facility is located in T1N, R3E, Sections 14, 22, 23, and 24 within the eastern part of Multnomah County, in Troutdale, Oregon (see Figure 1-1 in Section 1 of this report).

The study area is characterized by a mild temperate marine climate, with moderately warm, dry summers and wet winters. The average annual precipitation in the area is approximately 37 inches per year. Forty to fifty percent of the total annual precipitation falls in January and February [National Oceanic and Atmospheric Administration (NOAA) and U.S. Department of Commerce, 1974]. The average daily maximum temperature for the study area is 62 degrees Fahrenheit (°F), and the average daily minimum temperature is 44°F (Ecology and Environment, 1991).

Prevailing winds in the region are from the east and southeast in the spring and summer, and from the north and northwest in the fall and winter (NOAA and U.S. Department of Commerce, 1974).

2.2 Site Features

The RMC site is flat, bounded on the south by Graham Road, on the north by the Columbia River, on the east by the Sandy River, and on the west by Sundial Road. A U.S. Army Corps of Engineers (COE) flood control dike surrounds the plant on the northern and eastern sides (Figure 1-2). Areas north and east of the dike are located within the 100-year floodplain.

The developed portion of the site includes several main buildings: the potlines; casthouse; bakehouse; carbon plant; and wastewater treatment systems. The Bonneville Power Administration (BPA) maintains a substation in the northwestern portion of the site. Company Lake occupies a former channel of the Sandy River just north of the COE dike. CH2M HILL (1995a) provides additional descriptions of site features.

SECTION 3

HYDROGEOLOGY

Section 3
Hydrogeology

Previous studies focusing on the eastern part of the Portland Basin area (see Table 1-1 in Section 1) generally agree on the character and extent of the aquifer units, although the stratigraphic terminology used often differs, as illustrated in Figure 3-1. The units described in this report generally follow the more recent informal hydrogeologic-unit names adopted by Swanson et al. (1993). One exception to the nomenclature of Swanson et al. is the inclusion of Blue Lake Aquifer, which is located in the eastern part of the City of Portland's Columbia South Shore Wellfield. This aquifer, described by Hartford and McFarland (1989), correlates with the lower portions of the Unconsolidated Sedimentary Aquifer described by Swanson et al. and is included in this report because of its proximity to the RMC facility.

3.1 Regional Hydrogeologic Units

Table 3-1 is a summary of the regional hydrogeologic units present in the RMC site vicinity, and Figure 3-2 is a generalized regional stratigraphic column (Swanson et al., 1993). The geologic units of the Portland Basin, from youngest to oldest, generally include:

- Alluvium
- Flood Deposits
- Troutdale Formation
- Interfingered Sandy River Mudstone and Troutdale Formation
- Columbia River Basalt Group and Older Rocks

The sedimentary units (alluvium downward through interfingered Sandy River Mudstone and Troutdale Formation) filling the Portland Basin were formed by a variety of geologic processes and events that affected the character and course of the ancestral and present-day Columbia River drainage system. These units include cataclysmic, glacially derived, flood deposits of gravel, sand, and silt; volcanic mudflows of sand, silt, ash, gravel, and other volcanic debris deposited from nearby eruptive centers; and fine-grained sediments deposited in a closed-basin lacustrine environment.

The shallow Quaternary deposits are characterized by alluvial and fluviolacustrine sediments, primarily confined to the areas near current and former locations of the Columbia River and other major tributaries (Swanson et al., 1993). Recent alluvium and flood deposits collectively make up the Unconsolidated Sedimentary Aquifer (USA) and the Blue Lake Aquifer (BLA). These aquifers are stratigraphically similar in position but differ in grain size and, therefore, transmissivity. The base of the Quaternary deposits corresponds to the Troutdale Gravel Aquifer (TGA), which is primarily composed of coarser grained Pleistocene Troutdale Formation sediments.

System	Series	Trimble 1963 (Portland)	Mundorff 1964 (Clark County)	Hogenson and Foxworthy, 1965 (East Portland)	Willis 1977,1978 (Portland Well Field)	Hoffstetter 1984 (Portland Well Field)	Noble and Ellis 1960 (Vancouver)	Carr and Associates 1965 (South Clark County)	Hartford and McFarland, 1989 (Portland Well Field)	Swanson and McFarland, 1993 (Portland Basin)
		REFERENCE (AREA)								
QUATERNARY	Holocene	Alluvium and younger terrace deposits	Alluvium	Alluvium and younger terrace deposits	Un-named clayey silt and sand ?—? Columbia River Sands aquifer	Alluvium and flood plain deposits Columbia River Sands aquifer	Orchards aquifer	3A and 1A	Overbank deposits Columbia River Sand aquifer	Upper sedimentary subsystem: Unconsolidated sedimentary aquifer
QUATERNARY	Pleistocene	Lacustrine deposits Estacada Formation Gresham Formation Loess Springwater Formation Walters Hill Formation Boring Lava	Pleistocene alluvial deposits Glacial drift Boring Lava	Fluviolacustrine deposits Piedmont deposits Boring Lava	? Blue Lake aquifer ? Troutdale gravel aquifer	Blue Lake aquifer Parkrose gravel aquifer	Troutdale aquifer	1B and 2B 4B	Blue Lake gravel aquifer Unconsolidated gravel/ Troutdale gravel aquifer	Troutdale gravel aquifer
TERTIARY	Pliocene	Troutdale Formation Sandy River Mudstone	Troutdale Formation (upper member) Troutdale Formation (lower member)	Troutdale Formation Sandy River Mudstone	Un-named confining layer Troutdale sandstone aquifer Un-named confining layer Sandy River Mudstone aquifer ?—?	Parkrose aquitard Troutdale sandstone aquifer Rose City aquitard Rose City aquifer ?—?	?	1B and 2B ? 3B ? 1C	Confining unit 1 Troutdale sandstone aquifer Confining unit 2 Sand and gravel aquifer	Lower sedimentary subsystem / Fine-grained sedimentary rocks: Confining unit 1 Troutdale sandstone aquifer Confining unit 2 Sand and gravel aquifer ?
TERTIARY	Miocene	Rhododendron Formation Columbia River Basalt Group Scappoose Formation	Older rocks	Older rocks				4C		Older rocks
TERTIARY	Oligocene	Skamania Volcanic Series								
TERTIARY	Eocene									

Source: Swanson, R.D., and W.D. McFarland. 1993.

FIGURE 3-1
Comparison of Hydrogeologic Unit Terminology for the Portland Basin

REYNOLDS METALS COMPANY
TROUTDALE, OREGON
CH2M HILL

Table 3-1
Hydrogeologic Unit Summary
Reynolds Metals Company
Troutdale, Oregon

Hydrogeologic Unit Name (a) (b)	**Generalized Description**	**Depositional Setting**	**Estimated Unit Thickness** (feet)	**Typical Yields** (gpm) (c)	**Present Beneath Site?** (Y/N) (d)	**Comments**
Unconsolidated Sedimentary Aquifer (USA)	Gravel deposits, some boulders, with varying amounts of sand, silt, and clay.	Fluvial deposits: Late Pleistocene Columbia River *catastrophic flood deposits* and alluvial deposits from smaller tributaries.	up to 250' thick at site	5-6,000 gpm, 5-40 gpm for wells screened in clayey silt.	Yes	Unit generally recognizable in outcrop by lack of weathering beneath the oxidized upper 6 feet. Most RMC wells are likely screened in this unit.
Blue Lake Aquifer (same as USA)	Boulder, cobble, & gravel-sized clasts in a matrix of clayey to sandy silt. The coarse gravel includes 60-90% basalt and the rest is quartzite, granite and diorite.	Fluvial deposits: Coarser-grained channel deposits of ancestral Columbia River.	60-220	up to 10,000	No	Locally, unit is present beneath the eastern portion of the Portland Well Field, approximately 1 mile west of the RMC site.
Troutdale Gravel Aquifer (TGA)	Poorly to moderately cemented conglomerate & sandy conglomerate, and weakly to well consolidated sandy gravel with sandstone lenses and beds. Upper portion weathered loess and soil.	Derived from ancestral *Columbia River deposits* & Cascade Range volcanic conglomerate & sandstone.	0-800 but typically, 100-400	50-1,000	No	In many areas top of unit boundary is marked by cemented or clayey gravel. Likely removed by ancestral Columbia River erosion at site location.
Confining Unit 1 (CU1)	Siltstone & sandstone with some thin lenses of sandy tuffaceous silt & sand-stone, & clay. Dark olive-gray to brown-gray sand & clay. Black sand or sand-stone may occur in beds 5-15 ' thick.	Lacustrine (lake) bed deposits - *SRM* (e) *& fine-grained* portion of Troutdale *Fm,* deposited within a closed lacustrine basin.	less than 200 feet	poor yield, but local sand lenses targeted by domestic wells.	No	Likely removed by ancestral Columbia River erosion at site location.
Troutdale Sandstone Aquifer (TSA)	Coarse grained sandstone & conglomerate with lenses & beds of fine to medium sand & thin to blue-gray silty clay. Basalt gravel conglomerate at base of unit.	Fluvial deposits of Ancestral Columbia River. Corresponds to *coarser-grained* portion of *SRM & Troutdale Fm.*	100-200	up to 2,500	No	Unit thickest east of Sandy River closest to source area for sediments. Likely removed by ancestral Columbia River erosion at site location.

Table 3-1
Hydrogeologic Unit Summary
Reynolds Metals Company
Troutdale, Oregon

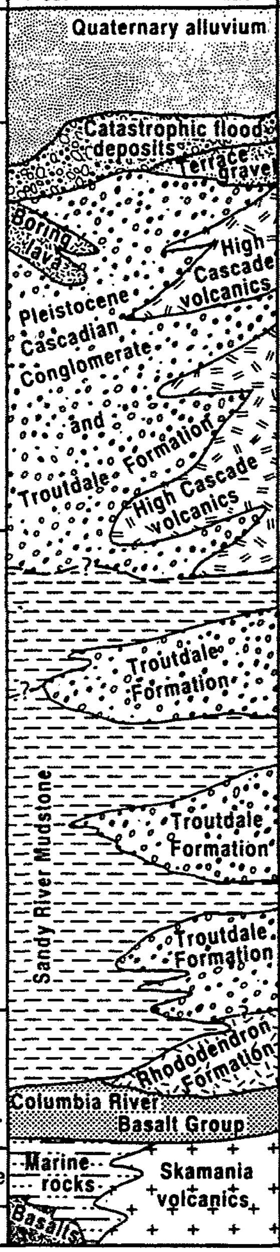
Hydrogeologic Unit Name (a) (b)	Generalized Description	Depositional Setting	Estimated Unit Thickness (feet)	Typical Yields (gpm) (c)	Present Beneath Site? (Y/N) (d)	Comments
Confining Unit 2 (CU2)	Grayish olive-green clay & silt with lenses of silt & fine-to-medium grained basaltic sand. Claystone present near base of unit.	Lacustrine deposits - *SRM* & *fine-grained* portion of *Troutdale Fm*. Deposited within a closed lacustrine basin.	less than 200 feet, (averaging ~ 40-100)	poor yield, lenses of silt & fine-grained sand 2-6' thick locally supply domestic wells.	No	Likely removed by ancestral Columbia River erosion at site location.
Sand and Gravel Aquifer (SGA)	Sand, gravel, silty sand, sand & clay. Upper portion may contain conglomerate with volcanic clasts in a sandy matrix overlain by sandstone. Generally fining downward.	Deposited by ancestral Columbia River - *coarse grained* sequence of *SRM.*	0-800 (approx. 200 feet at site)	5 to 3,000 gpm domestic wells: 5-30 gpm.	Yes	Some RMC wells appear to be screened in this unit.
Older Rocks	Lava flows & consolidated volcanic debris from the Rhododendron Fm, Columbia River Basalt Group (CRBG), & Skamania Volcanics. Also, marine sedimentary rocks: siltstone & sandstone.	*Volcanic* and *marine sedimentary* rocks.	Unknown	typically low, 5-10 gpm. Wells in CRB interflow zones- up to 1,000 gpm.	Yes	Marine rocks may contain saline water. CRBG used as source of water in upland areas where unit occurs at shallower depths. Outcrops at Ione Reef, just north of site.

Notes:

(a) Descriptions of Hydrogeologic Units in the RMC study area follow the informal hydrogeologic unit names adopted by Swanson (1993). One exception is the addition of the Blue Lake Aquifer as described by Hartford and McFarland, 1989. This unit is included within the Unconsolidated Sedimentary Aquifer by Swanson and McFarland, 1993.
(b) Hydrogeologic Units are presented from youngest (shallowest) to oldest (deepest).
(c) *gpm* = gallons per minute.
(d) "Beneath site" indicates area corresponding to T1N, R3E, Section 23.
(e) *SRM* = Sandy River Mudstone.
(f) Refer to Figure 3-2 for comparison of geologic units and aquifer units.

SYSTEM	SERIES	HYDROGEOLOGIC UNIT			LITHOLOGY
QUATERNARY	Holocene; Pleistocene	Upper sedimentary subsystem	Unconsolidated sedimentary aquifer		Silt, sand, and clay comprise flood plain deposits of the Columbia and Willamette Rivers. Alluvium along major tributaries is sandy gravel. Late Pleistocene catastrophic floods of the Columbia River deposits on the basin floor are bouldery gravel, sandy gravel, and sand with sandy silt extending to 400-foot altitude. Late Pleistocene terrace deposits are weakly consolidated thin sand and gravel beds.
	Pleistocene	Upper sedimentary subsystem	Troutdale gravel aquifer		Pleistocene volcaniclastic conglomerates derived from the Cascade Range are weakly to well consolidated sandy gravel with lithic sandstone lenses and beds. Troutdale Formation is cemented basaltic gravel with quartzite pebbles and micaceous sand matrix and lenses, as well as minor lithic-vitric sand beds. Boring lava that erupted from vents in the Portland area is fine to medium olivine basalt and basaltic andesite lava flows with less abundant pyroclastics. High Cascade Range volcanics are olivine basalts and basaltic andesite flows that erupted, and for the most part deposited east of the Sandy River. The upper 10 to 100 feet of the aquifer is weathered loess and residual soil.
? TERTIARY	? Pliocene	Lower sedimentary subsystem	Fine-grained sedimentary rocks	Confining unit 1	Bedded micaceous arkosic siltstone and sandstone with some thin lenses of lithic and vitric sandy tuffaceous silt and sandstone, and clay.
	Pliocene	Lower sedimentary subsystem	Fine-grained sedimentary rocks	Troutdale sandstone aquifer	Coarse vitric sandstone and basaltic conglomerate interlayered with siltstone, sandstone, and claystone.
	Pliocene	Lower sedimentary subsystem	Fine-grained sedimentary rocks	Confining unit 2	Bedded micaceous siltstone and sandstone with some thin lenses of lithic and vitric sand, tuffaceous silt and sandstone, and clay.
	Pliocene	Lower sedimentary subsystem		Sand and gravel aquifer	Discontinuous beds of micaceous sand, gravel, and silt with localized vitric sandstone lenses. Upper part is gravelly along the Columbia River in east part of study area; elsewhere, upper part is interlayered with micaceous sand, silt, and clay.
	Miocene; Oligocene; Eocene	Older rocks			Rhododendron Formation consists of lava flows and dense volcanic breccia. Columbia River Basalt Group is a series of basalt flows, some have fractured scoriaceous tops and bases. Marine sedimentary rocks are predominantly dense siltstones and sandstones. Skamania volcanics are dense flow rock, breccia and volcaniclastic sediment. Older basalts are sequences of flows with some breccia and sediment.

GEOLOGIC UNIT



Source: Swanson et al., 1993.

FIGURE 3-2

Summary of Hydrogeologic Units

REYNOLDS METALS COMPANY
TROUTDALE, OREGON

CH2M HILL

The geologic units or deposits that generally lie beneath the younger sedimentary deposits include the Sandy River Mudstone and the Troutdale Formation (see Figure 3-2). These Pliocene units tend to be more consolidated than the overlying Quaternary sedimentary deposits. Interfingered Sandy River Mudstone and Troutdale Formation contain, from youngest to oldest, Confining Unit 1 (CU1), Troutdale Sandstone Aquifer (TSA), Confining Unit 2 (CU2), and the Sand and Gravel Aquifer (SGA).

Older rocks of pre-Pliocene age are exposed in the southern Portland Basin; they include the Scappoose Formation and rocks of the Skamania Volcanic Series (Swanson et al., 1993). Extrusive igneous basalt flows of the Columbia River Basalt Group (CRBG) are believed to overlie the older rock deposits in the Portland area. However, the depth, thickness, and extent of the basalt flows are not well defined. Groundwater may be encountered within basalt interflow zones within the CRBG and/or within marine sedimentary rocks. Wells screened in proximity to marine sedimentary rocks may encounter saline groundwater.

Regional, or large-scale, cross sections are not presented in this report because the more regionally observed aquifer units are not present beneath the RMC site vicinity. Refer to Swanson et al. 1993 (Plates 1 and 2) for regional cross sections.

3.2 Site Hydrogeologic Units

CH2M HILL review of RMC production well driller's logs combined with published hydrogeologic interpretations (Swanson et al., 1993) indicates that the USA underlies the RMC facility to about -200 feet elevation, corresponding to a maximum thickness of up to 220 feet. Sediment types within the USA vary spatially because of the complex nature of the fluvial depositional environment in which they were deposited. The SGA is approximately 200 feet thick beneath the RMC site. As mentioned in the previous section, water-bearing zones TGA and TSA, and confining zones CU1 and CU2, are not present beneath the RMC facility. These units probably were removed through erosion by the ancestral Columbia River. The Older Rocks occur at about -550 feet elevation beneath the RMC facility (Swanson et al., 1993).

A surface map of the hydrogeologic units present in the study area vicinity is shown in Figure 3-3. This figure also shows the locations of subsurface hydrostratigraphic cross sections A-A′ and B-B′, which are presented in Figures 3-4 and 3-5, respectively. Appendix B contains selected well logs used to construct cross sections A-A′ and B-B′. The west-east trending cross section A-A′ shows the approximate easternmost extent of the coarse-grained gravel deposits associated with the Blue Lake Aquifer and the Columbia South Shore Wellfield. On the basis of available well log data, sediments appear to become finer grained from west to the east beneath the RMC facility and are laterally heterogeneous. Because fine-grained confining zones are absent east of City of Portland (COP) #13, the BLA is probably in hydraulic connection with the upper USA water-bearing zone located beneath the RMC site.

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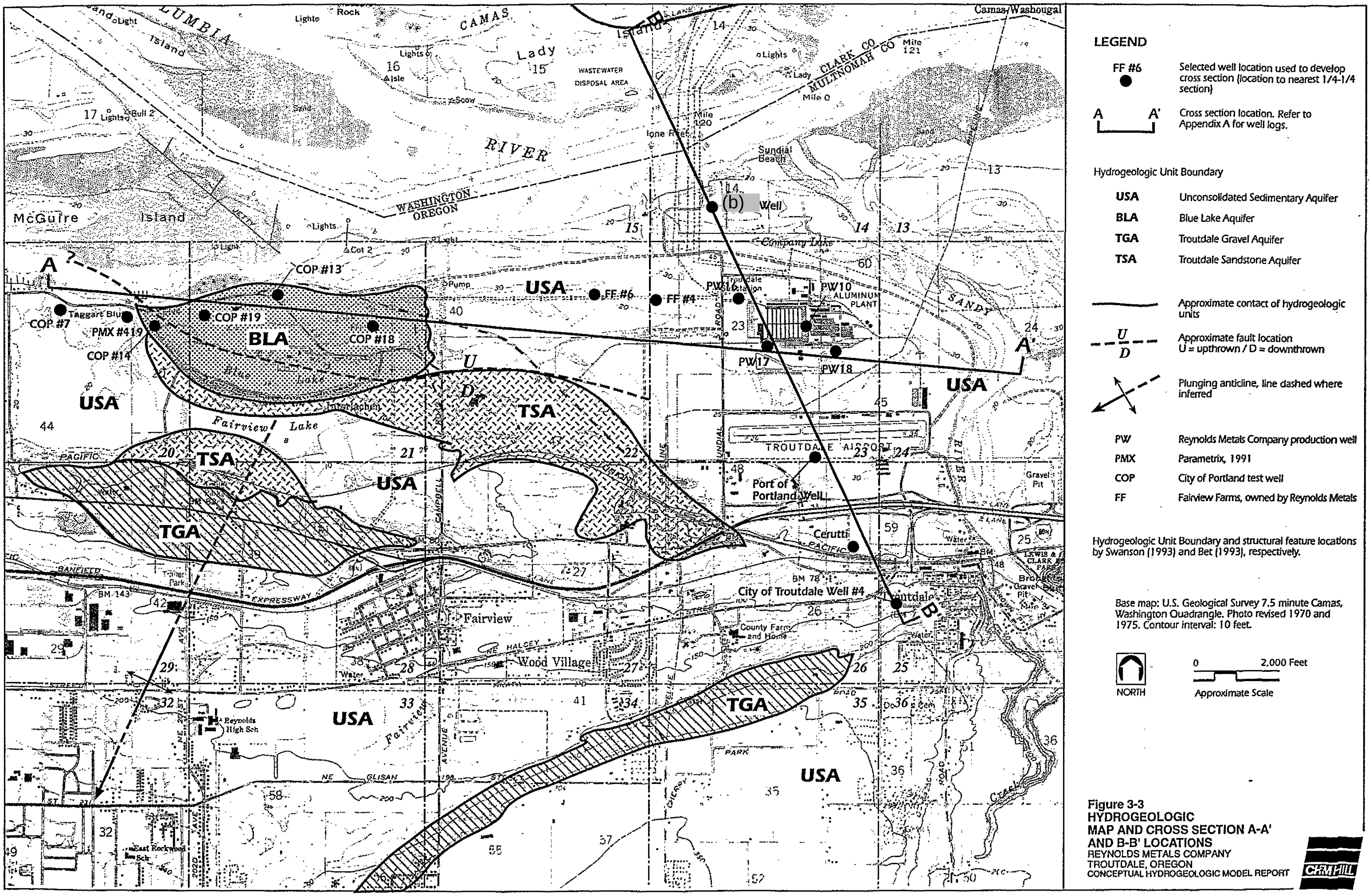
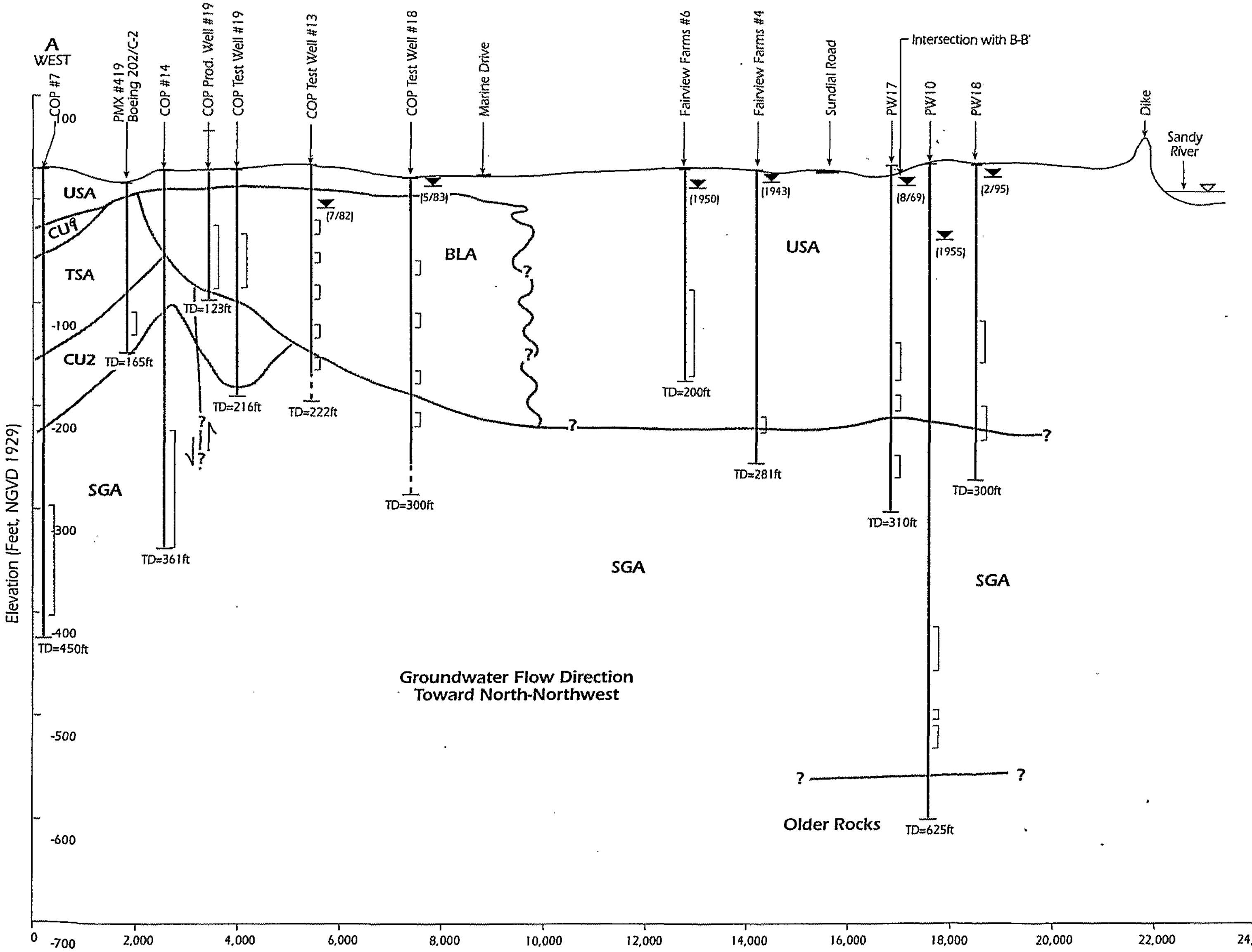
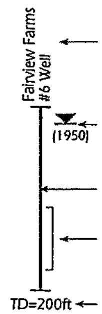


Figure 3-3
HYDROGEOLOGIC MAP AND CROSS SECTION A-A' AND B-B' LOCATIONS
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
CONCEPTUAL HYDROGEOLOGIC MODEL REPORT

CH2M HILL



LEGEND



- Well name or number. Refer to Figure 3-3 for well and cross section location map.
- Water level and date of measurement, shown for informational purposes
- Cased interval (dashed if backfilled)
- Screened or perforated interval
- Total well depth in feet below ground surface
- Approximate hydrogeologic unit contact

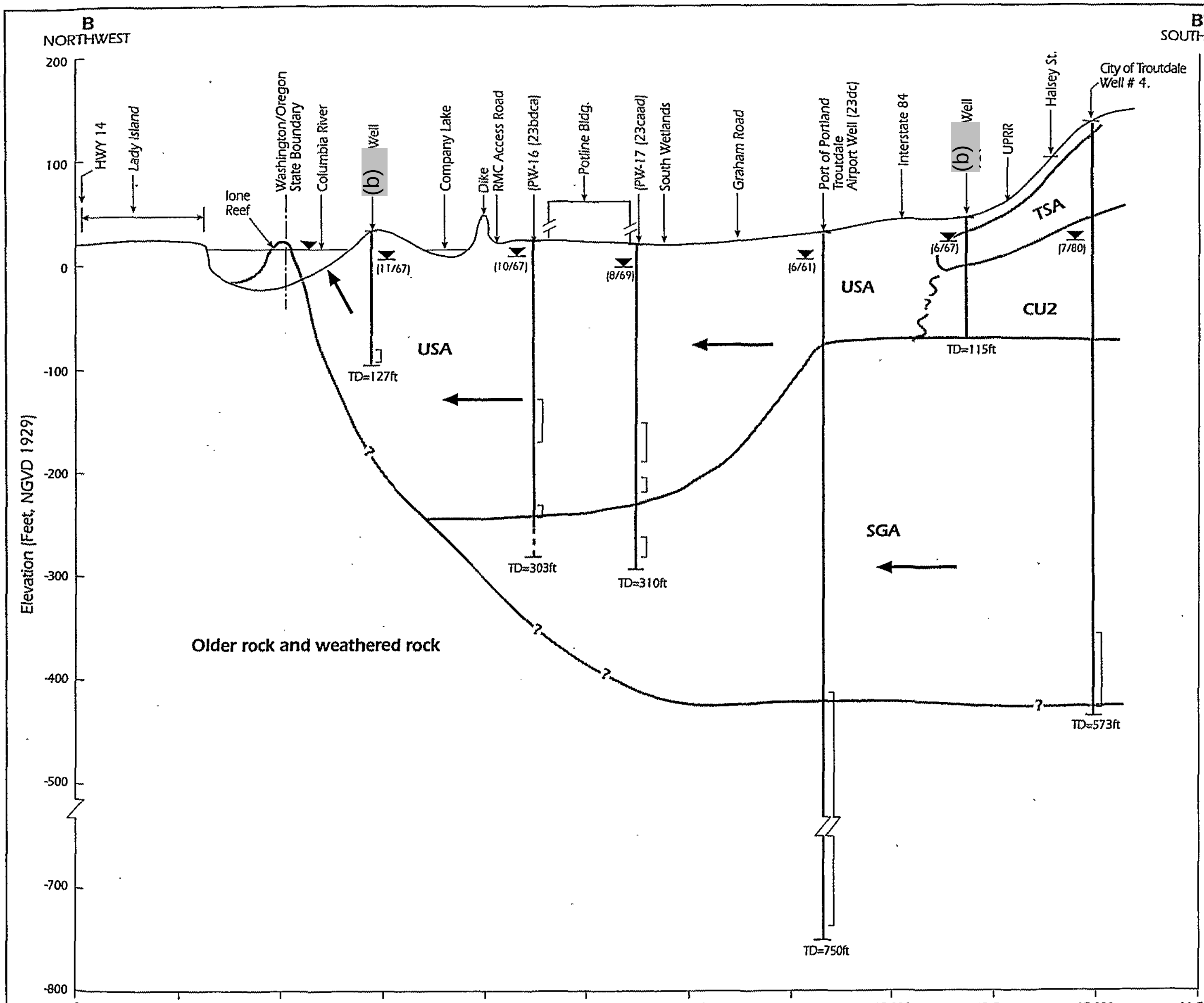
Notes:

1. Subsurface conditions depicted on cross sections are adapted from hydrogeologic unit boundaries as presented by Parametrix (1991) for the Blue Lake Aquifer only, Swanson (1993), and interpretations by the CH2M HILL hydrogeologist. Actual subsurface conditions may differ.
2. See Appendix A for well logs and Table 1-1for well summary information.
3. Topography and bathymetry of Columbia and Sandy Rivers estimated from the Camas 7.5-minute Quadrangle and information from the U.S. Army Corps of Engineers (July 1995).
4. Some wells are projected into the cross section plane.
5. Fault trace location based on Bet (1993).
6. See Table 3-2 for definitions of hydrogeologic unit names.

Horizontal scale: 1 inch = 2,000 feet
Vertical scale: 1 inch = 100 feet
Vertical exaggeration: 20x

Figure 3-4
HYDROGEOLOGIC CROSS SECTION A-A'
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
CONCEPTUAL HYDROGEOLOGIC MODEL REPORT

CH2MHILL



LEGEND

- Cerruti Well ← Well name or number. Refer to Figure 3-3 for well and cross section location map.
- (6/67) ← Water level and date of measurement, shown for informational purposes
- ← Cased interval (dashed if backfilled)
- ← Screened or perforated interval
- TD=115ft ← Total well depth in feet below ground surface
- Approximate hydrogeologic unit contact
- Generalized groundwater flow direction

Notes:

1. Subsurface conditions depicted on cross sections are adapted from hydrogeologic unit boundaries as presented by Parametrix (1991) for the Blue Lake Aquifer only, Swanson (1993), and interpretations by the CH2M HILL hydrogeologist. Actual subsurface conditions may differ.
2. See Appendix A for well logs and Table 1-1for well summary information.
3. Topography and bathymetry-of Columbia and Sandy Rivers estimated from the Camas 7.5-minute Quadrangle and information from the U.S. Army Corps of Engineers (July 1995).
4. Some wells are projected into the cross section plane.
5. Fault trace location based on Bet (1993).
6. See Table 3-2 for definitions of hydrogeologic unit names.

Horizontal scale: 1 inch = 2,000 feet
Vertical scale: 1 inch = 100 feet
Vertical exaggeration: 20x

Figure 3-5
HYDROGEOLOGIC
CROSS SECTION B-B'
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
CONCEPTUAL HYDROGEOLOGIC MODEL REPORT

Confining units CU1 and CU2, and the regional water-bearing units (including the TGA and TSA), are not present beneath the USA in the RMC site vicinity, possibly because of erosion by the ancestral Columbia River. Beneath the RMC site, the top of the SGA occurs at approximately 150 to 200 feet below ground surface (bgs) beneath approximately 150 feet of the USA. The well log from the deepest RMC production well (PW10) indicates a hard shale zone at about 550 feet bgs. It is probable that the "shale" referenced on the driller's log is a thin, platy basalt sequence rather than an actual shale unit, and it therefore likely represents the top of the Older Rocks sequence defined by Swanson et al. (1993).

Northwest-southeast cross section B-B′ in Figure 3-5 depicts the USA as a 250-foot-deep sedimentary channel beneath the RMC facility. This water-bearing unit appears to thin and terminate approximately one-half mile southeast of the site. Farther south, near the City of Troutdale, the geologic log for City Well #4 shows the USA and TSA present above a 120-foot-thick clay zone (CU2). City Well #4 taps groundwater from the SGA between 493 and 563 feet bgs.

The oldest rock encountered at the site is the Older Rocks unit that includes basalt flows and consolidated volcanic rock debris. This unit is reported to contain water-bearing marine sedimentary siltstone and sandstone sequences (Swanson et al., 1993). It is observed at a depth of approximately 450 feet bgs (Port of Portland Troutdale Airport Well) and crops out in the Columbia River to the north-northwest of the RMC site. Exposures are observed at Ione Reef (located at about river mile 120 in the Columbia River) and at the eastern border of Lady Island.

Figure 3-6 shows the RMC site vicinity map, monitoring well locations, and cross section locations C-C′ and D-D′, which are presented in Figures 3-7 and 3-8. These hydrogeologic cross sections have been developed from data contained on site-specific monitoring well soil boring logs and relevant published literature for the area. The cross sections are consistent with the description of heterogeneous shallow floodplain sedimentary deposits originating from the Columbia and Sandy Rivers.

North-south trending cross section C-C′ shows shallow (to about 35 feet bgs) floodplain deposits of the Columbia and Sandy Rivers (Figure 3-7). This figure shows an estimated spatial distribution of fine-grained silt and sandy silt sediments that compose the upper sediments at nearshore well locations MW09, MW21-25, and MW20. The stratigraphic relationships presented are based on existing data. Actual conditions are likely to be more heterogeneous than depicted. Cross section C-C′ indicates that sediments north of the dike (as observed in MW09, MW21-25, and MW20) are generally coarser (primarily sand) than those south of the dike (MW07, MW25-35), where silt was primarily observed. The thickest portion of the silt-dominated zone is about 25 feet, at MW07. Coarser grained sand occurs beneath the finer silt at MW25-35 and beneath the north landfill.

West-east trending cross section D-D′ (Figure 3-8) depicts subsurface sediments that are laterally heterogeneous across the southern portion of the site, also consistent with a dynamic fluvial depositional model. Soil boring logs indicate that a surficial sand layer may extend

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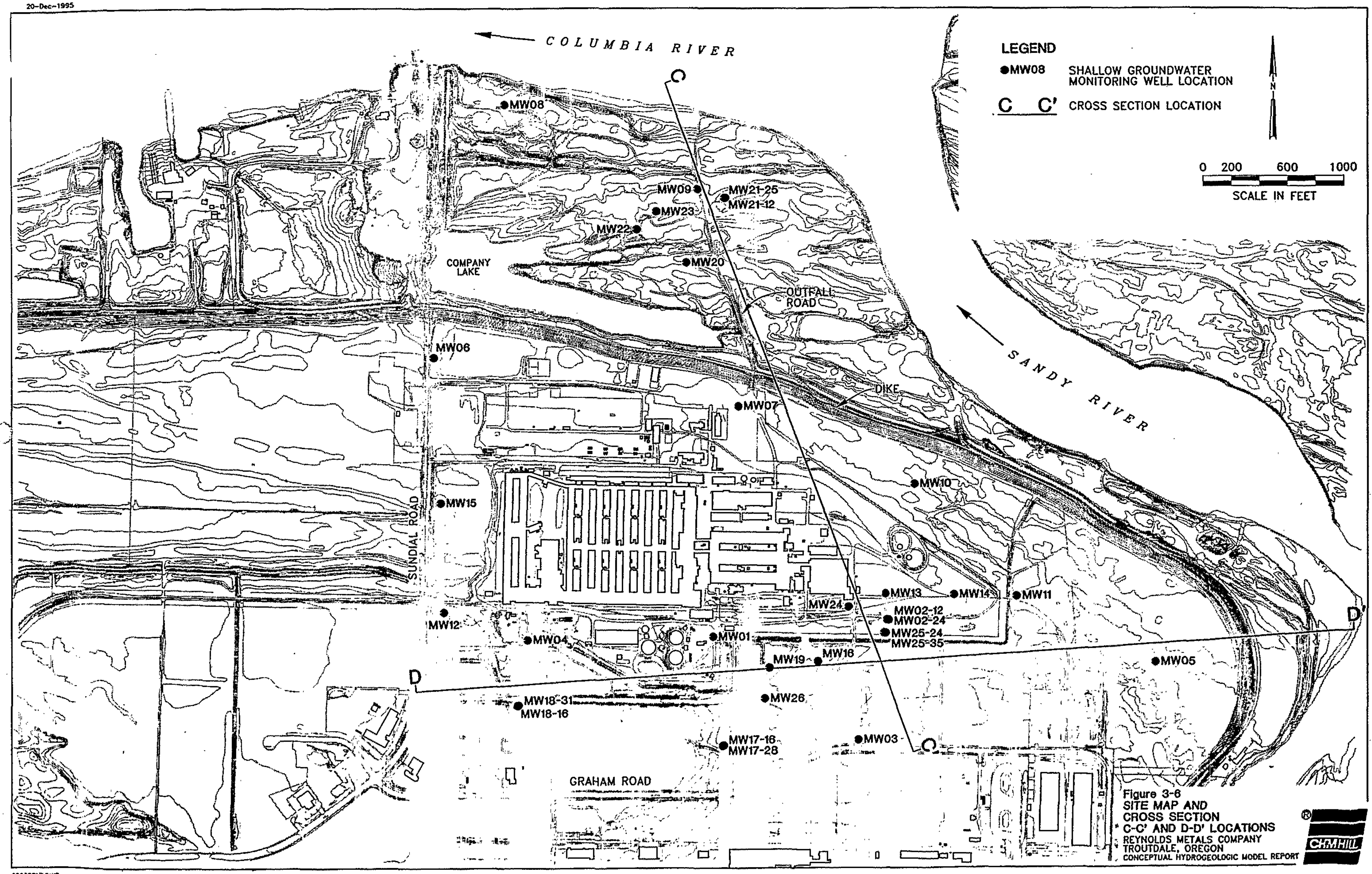
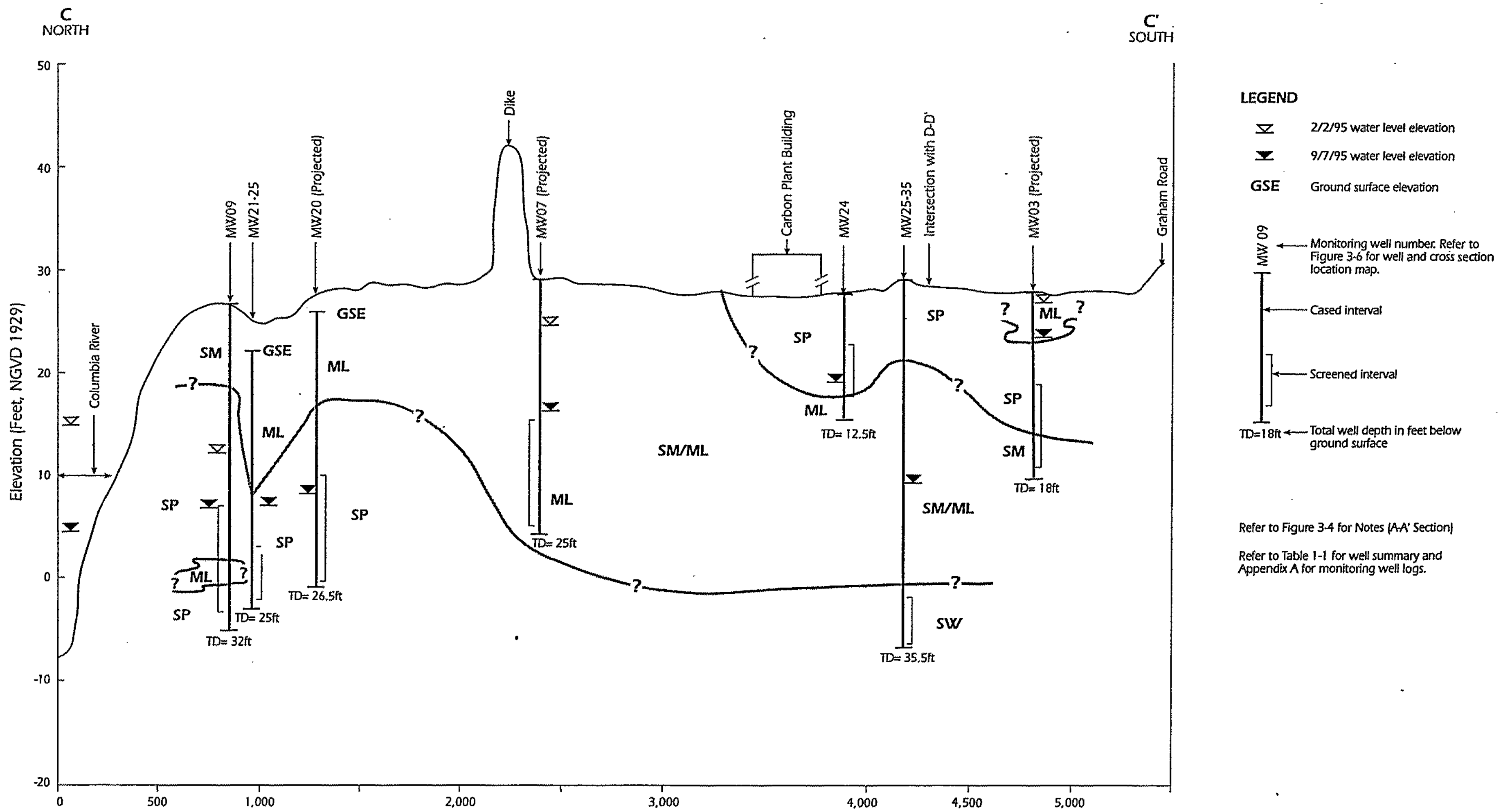


Figure 3-6
SITE MAP AND CROSS SECTION C-C' AND D-D' LOCATIONS
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
CONCEPTUAL HYDROGEOLOGIC MODEL REPORT

CH2MHILL

9293SG17.DWG

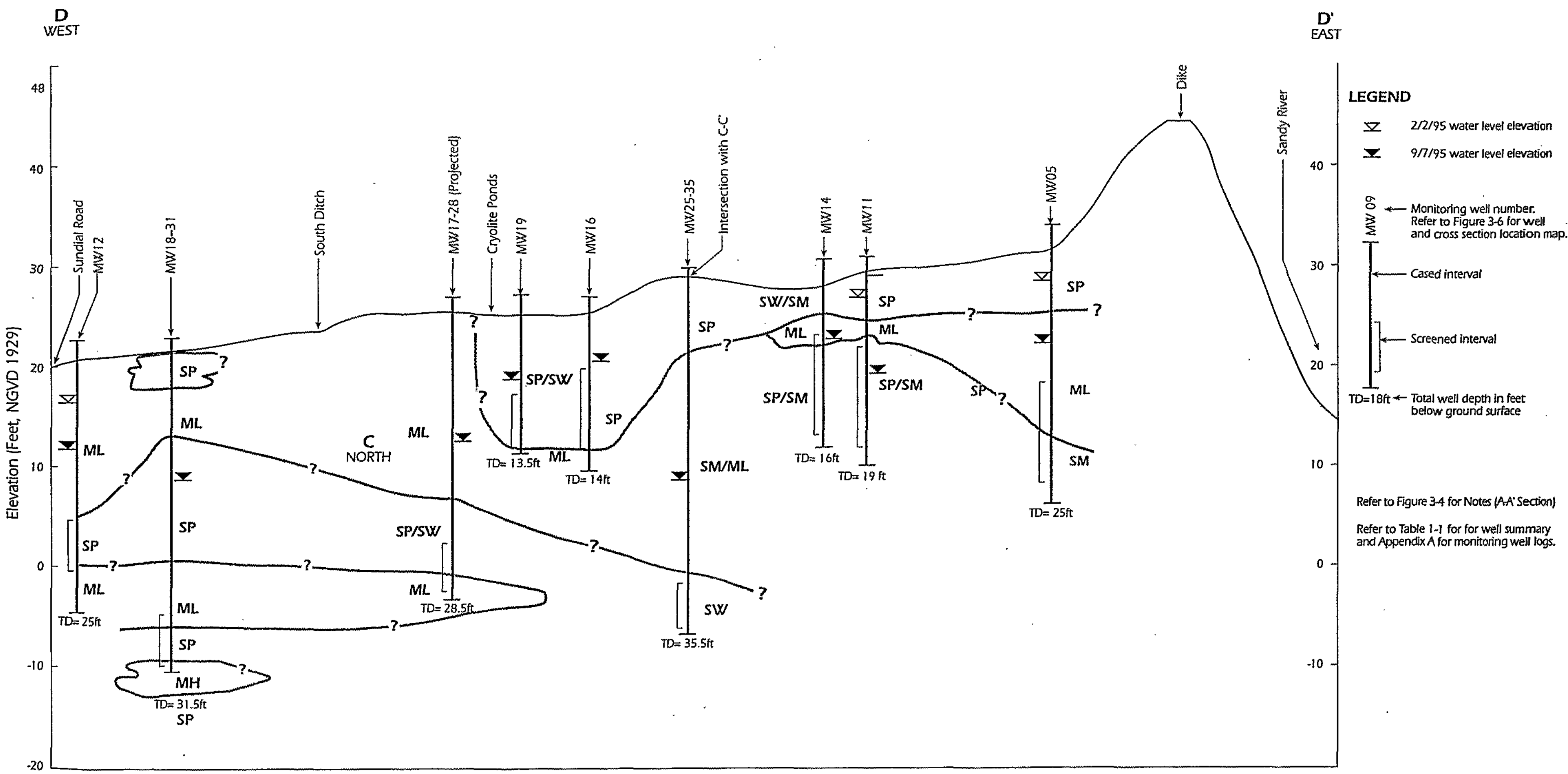


Horizontal scale: 1 inch = 500 feet
Vertical scale: 1 inch = 10 feet
Vertical exaggeration = 50x

Sand (SP and SW), silt (ML), and silty sand and sandy silt (SM/ML) comprise flood plain deposits of the Columbia and Sandy Rivers (Unconsolidated Sedimentary Aquifer (USA)).

Figure 3-7
HYDROGEOLOGIC CROSS SECTION C-C'
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
CONCEPTUAL HYDROGEOLOGIC MODEL REPORT

CH2M HILL



Refer to Figure 3-4 for Notes (A-A' Section)

Refer to Table 1-1 for for well summary and Appendix A for monitoring well logs.

Horizontal scale: 1 inch = 500 feet
Vertical scale: 1 inch = 10 feet
Vertical exaggeration = 50x

Sand (SP and SW), silt (ML), silt with clay (MH), and silty sand and sandy silt (SM/ML) comprise flood plain deposits of the Columbia and Sandy Rivers (Unconsolidated Sedimentary Aquifer (USA).

Figure 3-8
HYDROGEOLOGIC
CROSS SECTION D-D'
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
CONCEPTUAL HYDROGEOLOGIC MODEL REPORT

east to west from MW05 westward to MW19. West of MW19, silty sediments dominate the shallow subsurface. The variability in sediment types among wells is likely because of the complex nature of the fluvial depositional environment.

3.3 Structure

Northwest- and northeast-trending lineations, faults, and folds are present throughout the Portland Basin (Swanson et al., 1993). Eocene to Miocene volcanic and sedimentary rocks form topographic highs that predate deposition of the CRBG rocks and younger sediments. The older volcanic rocks, marine rocks, and Columbia River Basalt that underlie the basin-fill sediments are thought to be offset downward into the basin by faults that are poorly defined. Sedimentary rocks were deposited as a broad, shallow basin formed after the faulting. Small faults and folds deform these sediments, appearing to be both contemporaneous with and subsequent to deposition of the sedimentary basin-fill.

Bet and Rosner (1993) describe the hydrogeologic units in the Blue Lake area, approximately one mile west of the RMC facility. Structural contour maps they developed for the Blue Lake vicinity indicate that the structure of the study area is the result of several processes that include folding, faulting, and possibly fluvial channel incision. Their report concludes that the Troutdale Formation was folded into a large dome with the structural high located just south of Blue Lake; the structural dome is probably related to the southwest-trending plunging anticline described by Swanson et al. (1993). The anticline is located to the southwest of Blue Lake, as shown in Figure 3-3 (also partly within the western portion of cross-section A-A′ in Figure 3-4).

Data from driller's logs for the City of Portland Columbia South Shore Wellfield show that the upper portions of the Troutdale Formation are absent along the northeast flank of the structural high (Bet and Rosner, 1993). This is likely the result of erosion that occurred during large-scale flooding events associated with outbursts from Pleistocene-age glacial Lake Missoula. The general thickening trend in the Troutdale Formation toward the south and west of the Blue Lake area may be related to basin deformation and contemporaneous fluvial deposition. The folding of the Troutdale Formation in the area suggests that the basin deformation continued after the Troutdale Formation was deposited.

Information from borehole geophysical logs and other well logs indicates that the northeast portion of the structural dome was cut by the east-west trending fault shown in Figures 3-3 and 3-4 (Bet and Rosner, 1993). After uplifting Troutdale Formation units northeast of the fault, erosion appears to have removed the upper units, creating a trough along the fault plane that was later filled with coarse paleo-channel sediments (Blue Lake Aquifer).

These observations are consistent with well log interpretation and literature review specific to the RMC study area, where the upper units of the Troutdale Formation do not appear to be present. The TGA, Confining Unit 1, the TSA, and Confining Unit 2 appear to have been eroded from the RMC study area (Swanson et al., 1993).

SECTION 4

SURFACE WATER HYDROLOGY

Section 4
Surface Water Hydrology

The purpose of this section is to describe RMC surface water features and to identify the locations of features and drainage patterns for potential groundwater–surface water interaction at the RMC site. Water level measurements of RMC site surface water features (including ditches, creeks, lakes, wetland areas, and shallow groundwater) are used to evaluate groundwater–surface water interaction at the site. This section was developed to help assess the potential pathways and receptors of shallow groundwater onsite.

The primary surface water features near the RMC site are the Columbia River, the Sandy River, Company Lake, East Lake, Salmon Creek, an onsite drainage and stormwater ditch system, and the south wetlands. The Columbia and Sandy Rivers appear to be the primary surface water influences on shallow and deep water level elevations onsite. Near the RMC site, the Sandy River rises and falls in conjunction with daily tidal and longer term fluctuations observed in the Columbia River. The net movement of shallow groundwater appears to be toward the Columbia and Sandy Rivers, although brief and infrequent gradient reversals have been observed to occur within approximately 500 feet of the Columbia River.

Results of estimating river efficiency coefficients at the site resulted in:

- A narrow range of river efficiency coefficients over a wide area for deep wells

- Variable river efficiency coefficients at shallow monitoring well locations

Three factors appear to control shallow groundwater response to river stage fluctuations:

- Shallow aquifer permeability
- Proximity to the center of RMC pumping
- Distance from the river(s) to the monitoring wells

Because the elevation of Company Lake is controlled by a weir at the outfall ditch, and it receives relatively constant inflow from the plant, the lake elevation is not observed to vary in response to most groundwater or surface water elevation changes. However, when the Columbia River rises above elevation 20 feet (approximately), the river has been observed to flow into the lake via the outfall ditch. Data collected in July and August 1995 indicate that Salmon Creek may be recharging the shallow aquifer. During wetter portions of the year, when groundwater levels are high, shallow groundwater appears to discharge into the south wetlands and other onsite surface water drainage features.

4.1 Location of Surface Water Bodies

Surface water features and staff gauge locations for the RMC site and vicinity are shown in Figure 4-1. Staff gauge surface water levels are tabulated in Table 4-1. The primary surface water features at the site include the following:

- The Columbia River flowing east to west along the northern site boundary
- The Sandy River flowing southeast to northwest along the eastern site boundary
- Company Lake, lying north of the flood control dike near the northwestern site boundary
- East Lake, formerly connected to Company Lake, between Company Lake and the Sandy River
- Salmon Creek (formerly a natural waterway, now dredged and controlled) flows onsite from the south, and westward from the western property boundary
- Onsite drainage and stormwater ditch system
- South wetlands

Company Lake and East Lake are naturally occurring surface water features that were present before facility construction. The linear southeast-northwest depression that contains these features is probably an abandoned former channel of the Sandy River. Aerial photographs from the 1930s show that Company Lake, East Lake, and the Sandy River were once connected, and that a drainage channel had been cut from the northwest corner of Company Lake to the Columbia River prior to 1952. Review of aerial photographs shows a general decline in the number and size of onsite ponds and minor drainages from the 1930s through the 1960s. This gradual decline may be related to a declining water table caused by changing Columbia River management practices and by increasing surface water and groundwater use as nearby areas experienced greater demand because of population growth.

Aerial photographs taken in 1968 mark the beginning of a sand and gravel dredging operation on the north side of the west end of Company Lake. This operation (Gresham Sand and Gravel today) dredges sand from the bar at the mouth of the Sandy River and deposits the dredge spoils west and northwest of the present-day Company Lake. By 1971, the west end of the lake had been filled with dredge spoils, and a new drainage ditch was cut on the RMC property from the northwest corner of Company Lake north to the Columbia River. By 1990, the service road for the gravel operation that had formerly curved around the west end of the lake was straightened, forming the current western border of the lake.

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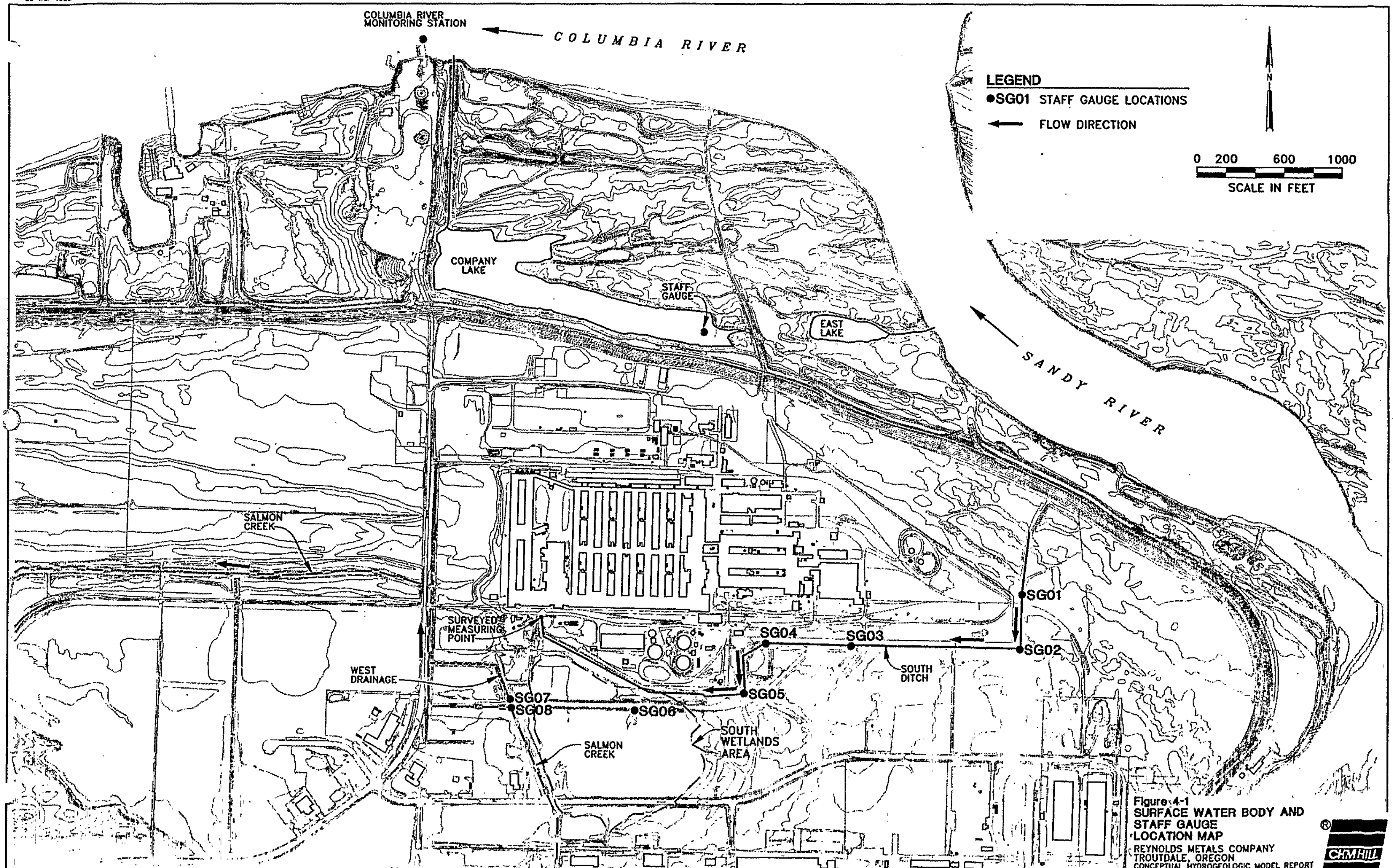


Figure 4-1
SURFACE WATER BODY AND STAFF GAUGE LOCATION MAP
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
CONCEPTUAL HYDROGEOLOGIC MODEL REPORT

9293SG21.DWG

Table 4-1
Manual Surface Water Data Summary
Reynolds Metals Company
Troutdale, Oregon

Company Lake		SG01		SG02		SG03		SG04		SG05		SG06		SG07		SG-08	
Date	Elevation	Date	Elevation	Date	Elevation	Date	Elevation	Date	Elevation	Date	Elevation	Date	Elevation	Date	Elevation	Date	Elevation
7/18/94 9:45	15.24	2/24/95 14:47	25.77	2/24/95 8:26	25.67	8/1/95 10:00	20.86	8/1/95 9:55	17.64	8/1/95 9:50	16.89	8/1/95 9:50	Dry	8/1/95 9:45	Dry	8/1/95 9:45	13.98
7/19/94 11:15	15.28	2/27/95 8:24	25.88	2/27/95 14:49	25.65	8/3/95 10:10	20.84	8/3/95 10:05	17.84	8/3/95 9:55	17.00	8/3/95 9:50	Dry	8/3/95 9:50	Dry	8/3/95 9:50	13.98
7/20/94 9:00	15.29	2/28/95 12:28	25.75	2/28/95 12:36	25.63	8/7/95	Dry	8/7/95	17.81	8/7/95	16.93	8/7/95	Dry	8/7/95	Dry	8/7/95	13.98
7/21/94 8:00	15.31	3/1/95 8:35	25.72	3/1/95 8:50	25.62	8/24/95 10:35	Dry	8/24/95 10:35	17.83	8/24/95 10:20	16.98	8/24/95 10:20	Dry	8/24/95 10:15	Dry	8/24/95 10:15	13.90
7/25/94 2:15	15.37	3/3/95 8:16	25.67	3/3/95 8:29	25.59	9/7/95	Dry	9/7/95	17.68	9/7/95	16.91	9/7/95	Dry	9/7/95	Dry	9/7/95	13.90
7/26/94 8:43	15.32	3/6/95 11:04	25.67	3/6/95 11:18	25.58	10/5/95 12:05	Dry	10/5/95 12:00	17.61	10/5/95 11:35	16.77	10/5/95 11:30	Dry	10/5/95 11:25	Dry	10/5/95 11:25	14.74
7/27/94 10:15	15.35	3/13/95 8:49	25.83	3/13/95 8:47	25.64	10/16/95 16:05	Dry	10/16/95 16:00	17.61	10/16/95 15:55	16.83			10/16/95 13:50	Dry	10/16/95 15:50	14.61
7/28/94 8:33	15.34	3/14/95 9:27	25.90	3/14/95 9:30	25.70	10/18/95 17:20	Dry	10/18/95 17:20	17.61	10/18/95 17:35	16.80	10/18/95 18:00	Dry	10/19/95 17:30	Dry	10/19/95 17:30	14.91
7/29/94 8:53	15.38	3/15/95 8:12	25.88	3/15/95 8:10	25.67	10/19/95 17:10	Dry	10/19/95 17:10	17.61	10/19/95 17:20	16.78	10/19/95 17:25	Dry	10/20/95 18:50	Dry	10/20/95 18:50	14.90
8/8/94 10:30	15.39	3/16/95 8:56	25.84	3/16/95 8:58	25.66	10/20/95 18:25	Dry	10/20/95 18:25	17.61	10/20/95 18:35	16.78	10/21/95 13:30	Dry	10/21/95 10:10	Dry	10/21/95 10:10	15.02
8/15/94 10:20	15.40	3/17/95 8:15	25.81	3/17/95 8:17	25.64	10/21/95 13:45	Dry	10/21/95 13:35	17.58	10/21/95 1:35	16.78	11/3/95 13:00	Dry	11/3/95 13:05	Dry	11/3/95 13:05	15.41
8/16/94 16:55	15.47	3/18/95 8:27	25.81	3/18/95 8:29	25.62	11/3/95 13:20	Dry	11/3/95 13:35	17.80	11/3/95 1:10	16.91						
8/17/94 9:07	15.40	3/20/95 8:28	25.93	3/20/95 8:29	25.73												
8/18/94 7:48	15.40	3/22/95 8:51	25.90	3/22/95 8:53	25.68												
8/19/94 7:56	15.40	3/24/95 8:20	25.80	3/24/95 8:22	25.64												
8/22/94 8:04	15.48	3/25/95 8:49	25.69	3/25/95 8:50	25.58												
8/23/94 7:56	15.48	4/4/95 10:00	25.45	4/4/95 10:01	25.34												
8/25/94 8:56	15.45	5/3/95 10:40	25.58	5/3/95 10:40	25.42												
8/26/94 7:49	15.40	6/6/95 8:30	Dry	6/6/95 8:30	Dry												
8/29/94 8:26	15.39	10/5/95 10:20	Dry	10/5/95 10:25	Dry												
8/30/94 8:15	15.39	10/16/95 16:30	Dry	10/16/95 16:30	Dry												
8/31/94 8:25	15.38	10/18/95 17:08	Dry	10/18/95 14:05	Dry												
9/1/94 7:48	15.38	10/19/95 16:50	Dry	10/19/95 16:50	Dry												
9/2/94 6:53	15.38	10/20/95 17:45	Dry	10/20/95 17:45	Dry												
9/8/94 15:38	15.40	10/21/95 12:10	Dry	10/21/95 12:10	Dry												
9/19/94 10:01	15.60	11/3/95 12:10	Dry	11/3/95 12:10	Dry												
9/23/94 8:47	15.65																
9/30/94 9:12	15.70																
10/7/94 10:08	15.55																
10/21/94 11:36	15.60																
10/28/94 11:35	15.85																
12/13/94 11:55	15.40																
1/4/95 11:15	15.30																
2/2/95 10:54	16.10																
2/17/95 11:50	15.80																
3/1/95 9:42	15.43																
4/4/95 8:30	15.40																
5/3/95 9:20	15.60																
6/6/95 9:50	15.61																
6/28/95 12:10	15.40																
8/1/95 12:10	15.55																
9/7/95 10:10	15.60																
10/5/95 13:10	15.60																
10/16/95 17:30	15.60																
11/3/95 11:00	15.45																
Average	15.47	Average	25.77	Average	25.61	Average	20.85	Average	17.69	Average	16.86	Average	NA	Average	NA	Average	14.48
Minimum Value	15.24	Min. Value	Dry	Min. Value	Dry	Min. Value	Dry	Min. Value	17.58	Min. Value	16.77	Min. Value	Dry	Min. Value	Dry	Min. Value	13.90
Maximum Value	16.10	Max. Value	25.93	Max. Value	25.73	Max. Value	20.86	Max. Value	17.84	Max. Value	17.00	Max. Value	Dry	Max. Value	Dry	Max. Value	15.41
Summer Min.	15.24																
Summer Max.	15.70																
Winter Min.	15.30																
Winter Max.	16.10																

Notes: Staff gauge elevations in feet, 1929 NGVD.
"Dry" readings are not considered when developing average values.

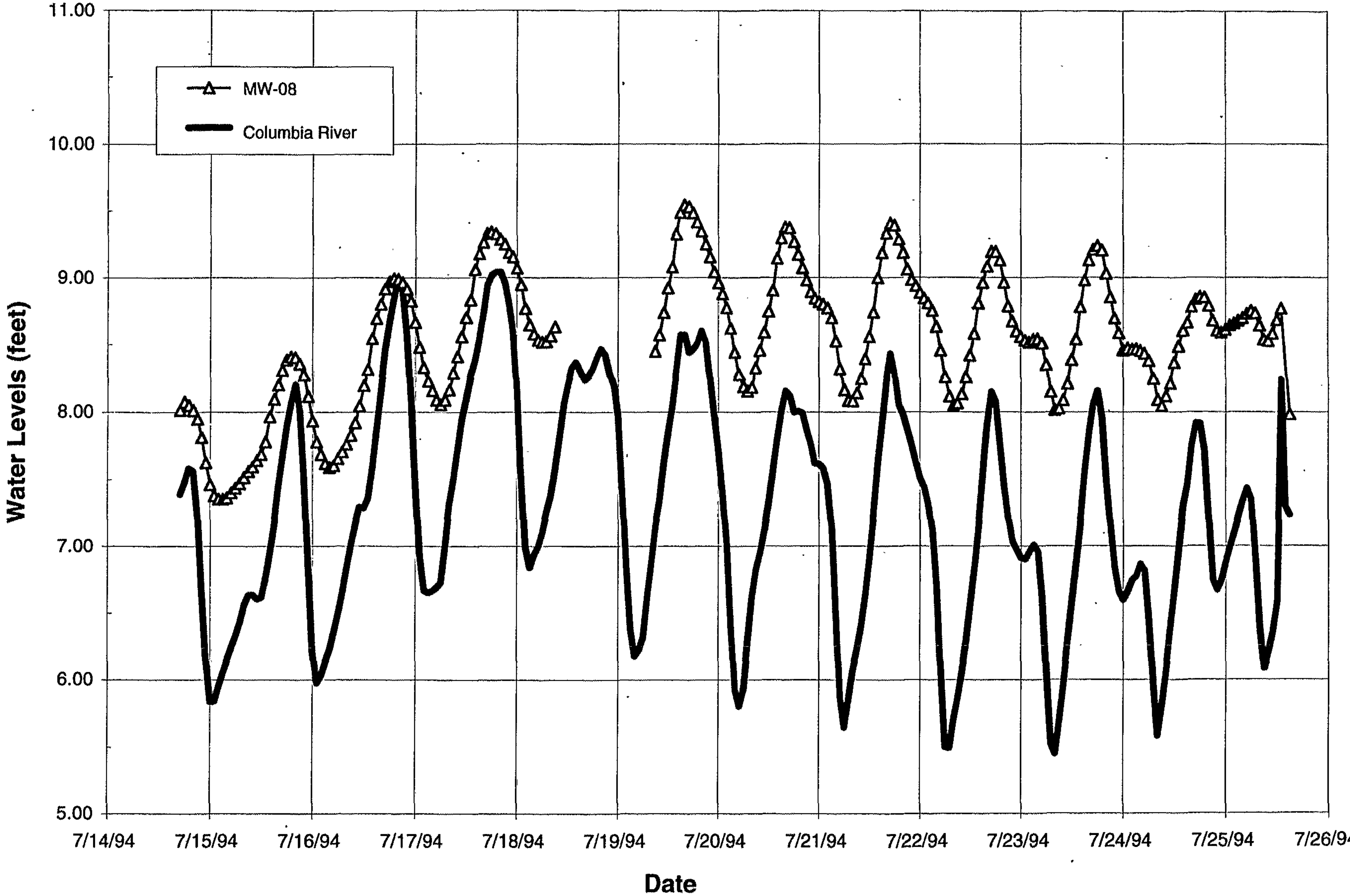
Onsite drainage ditches collect stormwater runoff, water produced from bakehouse dewatering activities, and all onsite process and treated wastewater. Beginning in approximately 1948, wastewater was discharged into Company Lake, after solids had settled in what is now the south wetlands area. Improvements made to the wastewater treatment system in 1964 eliminated the use of the south wetlands area as a process settling pond, and all collected stormwater and treated wastewater was routed directly from the South Ditch into Company Lake. The discharge from Company Lake to the Columbia River is regulated by DEQ under an existing National Pollutant Discharge and Elimination System (NPDES) permit (No. 100757). As part of the conditions of that permit, the water flowing from Company Lake into the Columbia River is monitored for both flow volume and selected constituent concentrations.

In 1968, additional drainage channels were cut into the south wetlands area to enhance drainage into Salmon Creek, and surface water in that area gradually declined. Currently, surface water exists in portions of the south wetlands area only during the winter months. Salmon Creek has been re-routed to bypass the wetlands area, and it currently flows onsite from the south, and flows west from the western site boundary. Salmon Creek originates near the City of Troutdale and receives discharge from the city's urban stormwater runoff, discharge from shallow groundwater, influent from local drainage ditches upgradient of the RMC site, and from the West Drainage (draining the south wetlands area) at the RMC western site boundary.

In general, stormwater, groundwater, surface water, and process/effluent exit at the site through two primary drainage routes. These drainages include the north side of the north dike (or the Company Lake outfall into the Columbia River) and the West Drainage that drains the south wetlands area.

4.2 Surface Water Interaction with Groundwater

Variation in surface water elevations appears to influence both shallow and deep groundwater levels at the site. The primary surface water influence on water level elevations onsite appears to be the Columbia River. The Columbia River stage changes in response to runoff, releases, and impoundments made by COE and ocean tidal response transmitted upriver from the mouth, approximately 140 miles to the west. COE reservoir management practices and precipitation trends can result in river stage changes of approximately 10 feet seasonally. Tidal responses cause twice-daily stage changes of between 2 and 3 feet, as shown in Figure 4-2. According to COE staff (Cassidy, 1995), recent dam releases along the Columbia River are related to:



Break in line indicates data gap

Figure 4-2
Dry Season Columbia River Tidal Variations vs. MW08 Groundwater Levels
Reynolds Metals Company
Troutdale, Oregon

J:\39293\grnd\watlev\WL794695.XLS\dry season 1994 Col. R. & MW-8

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- Fisheries or northwest salmon issues. In recent years, fisheries issues have increased in importance in the decision-making process for the quantity of water being released through the dams. Many reservoirs or lakes along the Columbia River were drawn down or are planned to be drawn down in the near future. Management efforts to enhance salmonid survival will continue to be a major factor in terms of quantity of water being released during migration of fish species through the river system; therefore, the quantity released is expected to remain variable.

- Northwest power planning issues are also taken into account in terms of providing utility power needs during peak demand periods in the area.

- Precipitation volume (controlled versus uncontrolled releases). During the past few years, prior to 1995, the Pacific Northwest was considered to be under drought conditions and an overabundance of precipitation was usually not a factor in water quantities released through the dams. Quantities were considered "controlled" or were designed to meet target flows. However, 1995 is considered a high or above-average precipitation year, and "uncontrolled spills" have been initiated during peak precipitation events to sustain target flows through the dams.

Although water levels onsite appear to respond primarily to stage fluctuations of the Columbia River, other surface water features (such as the Sandy River, the south wetlands area, and West Drainage/Salmon Creek) appear to cause localized groundwater flow direction and elevation variations. The influence of the individual surface water features on groundwater elevations and flow directions is discussed below.

4.2.1 Columbia River

Shallow groundwater levels at MW08 and MW09 show fluctuations similar to Columbia River stage and daily tidal variations. Figure 4-2 presents river level and MW08 groundwater elevation data for one week of July 1994, which is representative of the remainder of the data collected at these locations. This time period generally corresponds to dry season conditions when water elevations near the river range from approximately 6 to 9 feet. Water levels are higher at MW08, indicating shallow groundwater flows to the north, toward the Columbia River. The 2- to 3-foot daily fluctuations in water levels for the Columbia River are typical of observed river tidal variations. The similar magnitude (an approximate 2:1 response ratio) and nearby simultaneous nature of the groundwater response to river stage fluctuations indicate a strong hydraulic connection between the river and the shallow portion of the aquifer in this area.

Water level elevation measurements indicate that similar short-term gradient reversals (though of much smaller magnitude) also occur at MW09. Although the elevation of the base of the north landfill is unknown, periodic inundation of waste material may result from the water level elevation changes measured at MW09. This effect appears to be confined to the area north of the dike; no groundwater elevations (other than deep production well water levels affected by nearby pumping) south or west of the dike were observed to be lower than Columbia and Sandy River elevations (through November 1995). Although water level elevation data evaluated for this report extend from July 1994 through November 1995, it should be noted here that surface water elevations in the Columbia and Sandy Rivers (including Company Lake) rose to approximately 31 feet during the flooding that occurred in February 1996. This elevation is higher than ground surface elevations across most of the site and resulted in artesian conditions at several former production wells (FF04, FF06, PW16, PW17) and one shallow monitoring well (MW18-31).

Figure 4-3 shows the February and April 1995 wet season groundwater elevations at MW08 and the Columbia River, when water levels range from approximately 7 to 13 feet. This figure shows less divergence between the shallow aquifer system elevation and the Columbia River, and a lower amplitude (generally 1 to 2 feet) tidal variation. In general, the shallow groundwater elevation is higher than the Columbia River, except for periods when peak tidal river elevations were higher than MW08 groundwater elevations.

Because of the infrequent nature and relatively short duration of the gradient reversals, the net movement of groundwater is toward the Columbia and Sandy Rivers. It is unlikely that the brief gradient reversals result in a significant volume of surface water entering the aquifer from the river.

Not all wells monitored at the site (both production wells and monitoring wells) respond to short-term river stage fluctuation. Although response to river stage changes generally diminishes with increased distance from the river, some wells exhibit either unexpectedly small or absent response. As part of the aquifer test analysis presented in Section 5, a river efficiency was calculated at monitoring locations that had both adequate data frequency and sufficient amplitude of response to allow an efficiency calculation.[1] The results of that analysis are presented in Figure 4-4. The river efficiency at the deeper production wells where a river efficiency was calculated (FF04, FF06, and PW16) ranged from 0.73 to 0.78 (73 to 78 percent efficiency). This narrow range of efficiencies over a wide area suggests that most of the deeper production wells screened over similar intervals would exhibit a similar efficiency. Although water levels in production wells monitored closer to the central portion of the site appear to reflect the long-term river stage trends, the response to onsite pumping is large relative to river stage fluctuations, and the resulting "noise" in the data prevents the estimation of river efficiency at these locations.

At shallow monitoring well locations where sufficient data were collected for analysis, the river efficiency coefficient is variable because of differences in permeability across the site. These differences allow pressure responses from river stage changes to be transmitted to the shallower portion of the aquifer more efficiently at some locations than others. In addition, the deeper monitoring wells (deeper than 25 feet bgs) generally exhibited a slightly increased response to both pumping and the river than the shallower monitoring wells. It appears

[1] River efficiency is defined as the ratio of change of water level response over river level stage response (Walton, 1970).

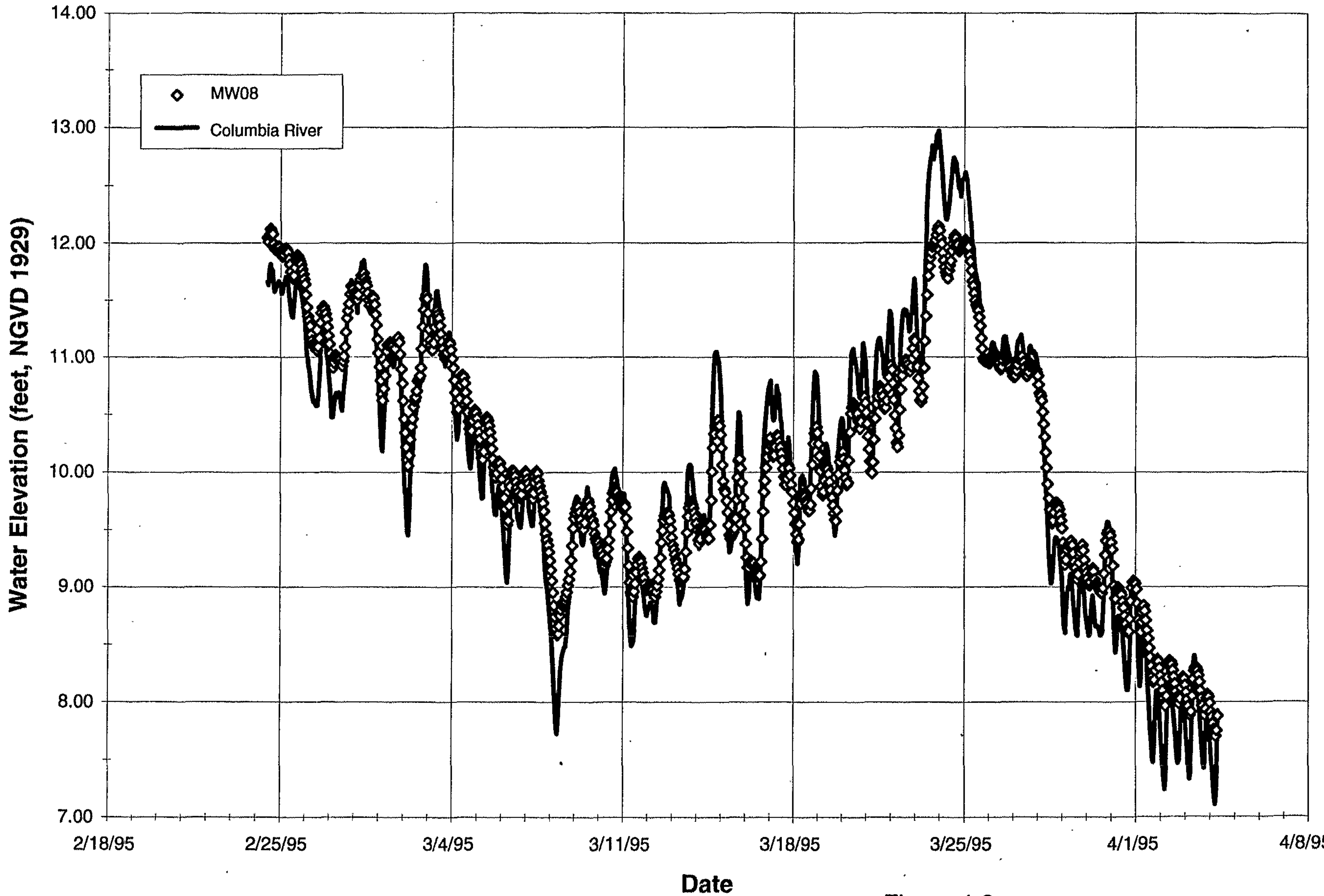
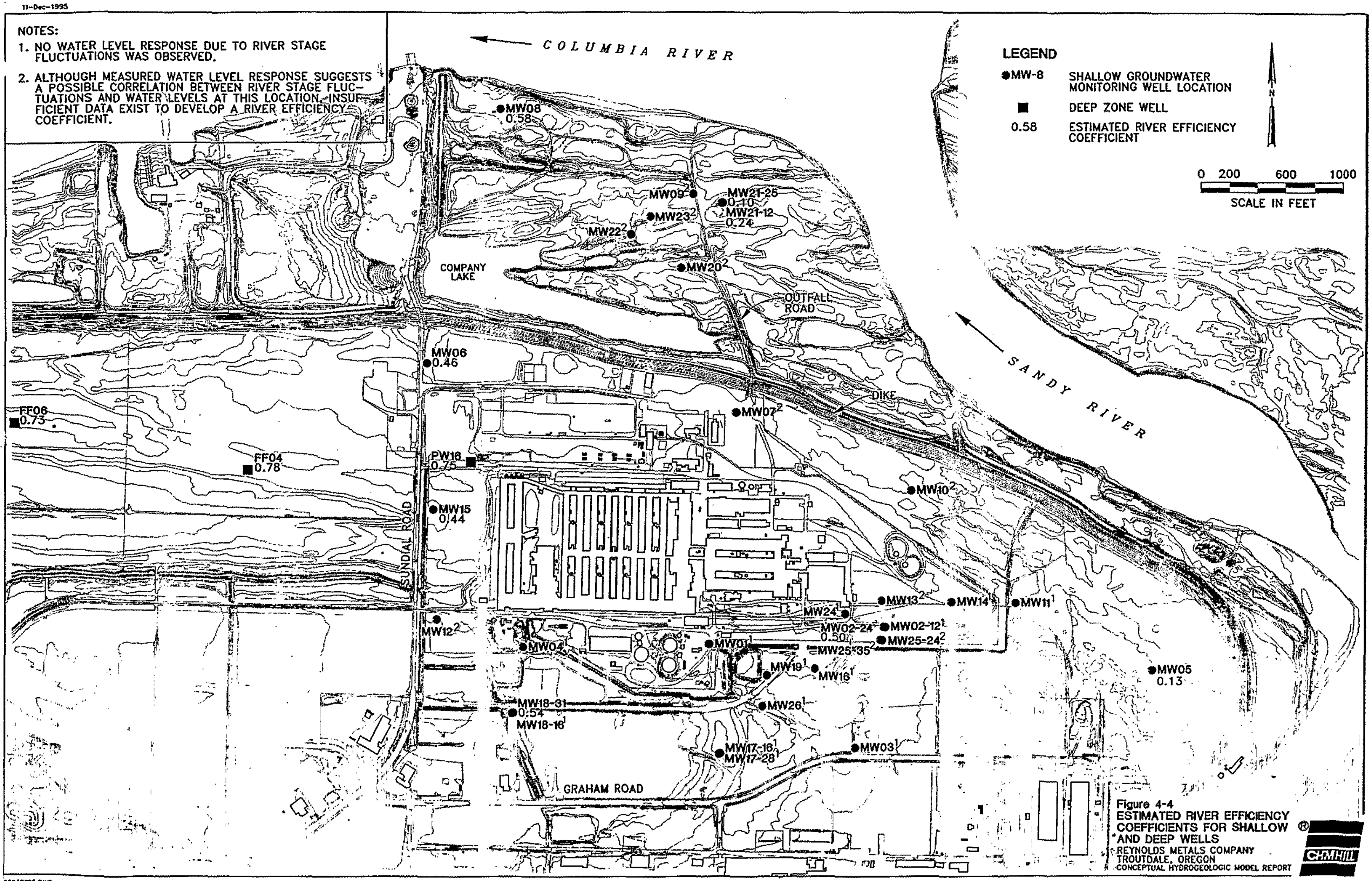


Figure 4-3
Wet Season Columbia River Levels vs. MW08 Groundwater Levels
Reynolds Metals Company
Troutdale, Oregon

ALR 9293SG25.DWG
11-Dec-1995



NOTES:

1. NO WATER LEVEL RESPONSE DUE TO RIVER STAGE FLUCTUATIONS WAS OBSERVED.
2. ALTHOUGH MEASURED WATER LEVEL RESPONSE SUGGESTS A POSSIBLE CORRELATION BETWEEN RIVER STAGE FLUCTUATIONS AND WATER LEVELS AT THIS LOCATION, INSUFFICIENT DATA EXIST TO DEVELOP A RIVER EFFICIENCY COEFFICIENT.

LEGEND

●MW-8	SHALLOW GROUNDWATER MONITORING WELL LOCATION
■	DEEP ZONE WELL
0.58	ESTIMATED RIVER EFFICIENCY COEFFICIENT

Figure 4-4
ESTIMATED RIVER EFFICIENCY COEFFICIENTS FOR SHALLOW AND DEEP WELLS
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
CONCEPTUAL HYDROGEOLOGIC MODEL REPORT

CH2MHILL

9293SG25.DWG

likely that the deeper portions of the aquifer (where higher permeability layers or lenses appear prevalent) respond more uniformly to river stage changes than does the shallow portion of the aquifer, which has been observed to be highly heterogeneous. However, the response is muted near the production wells, where pumping masks the aquifer response to the river. It is likely that the muted response near the production wells (PW03, PW07, PW08, and PW10) also results in a muted shallow aquifer response in the central portion of the plant (for example, at MW14, MW24, and MW01). In addition, the shallow wells most distant from the river (MW03, MW17-16, MW17-28) do not appear to respond (probably because of diminishing response in the deep zone), although deeper wells might record tidal influence, as indicated by the MW18 well pair.

Therefore, three factors appear to control shallow groundwater response to river stage fluctuations:

- Shallow aquifer permeability
- Proximity to the center of pumping
- Distance from the river(s)

Although vertical gradients may be variable in areas where the shallow aquifer has little (if any) response to river stage fluctuations, sitewide groundwater elevation changes are not likely to cause variable groundwater flow directions.

In two locations where data logger and pressure transducer assemblies were temporarily installed, MW21-12 and MW05, the response to river stage changes appeared to change with time. Water level elevations at MW05 are compared with Columbia River elevations in Figure 4-5. The variable river efficiency at MW05 is not likely to be an actual function of time. It is more likely related to the downward groundwater elevation trend that may have decreased the degree of hydraulic connection between surface water and groundwater by dewatering a layer or lens that is in good connection with the river. It is likely that the water level at MW05 begins responding to river stage changes again in the winter months when water levels rise, saturating the connected layer.

A similar pattern is exhibited in Figure 4-6, which compares the water level at MW21-12 with Columbia River elevation. In this case, the trend is from dry-season lower water levels to higher winter water levels, when the well begins to respond.

4.2.2 Sandy River

Surface water elevation measurements were collected from the Columbia and Sandy Rivers, and from the onsite staff gauge locations. The Sandy River staff gauge measurements were discontinued (and the staff gauge eventually removed) because of the close agreement

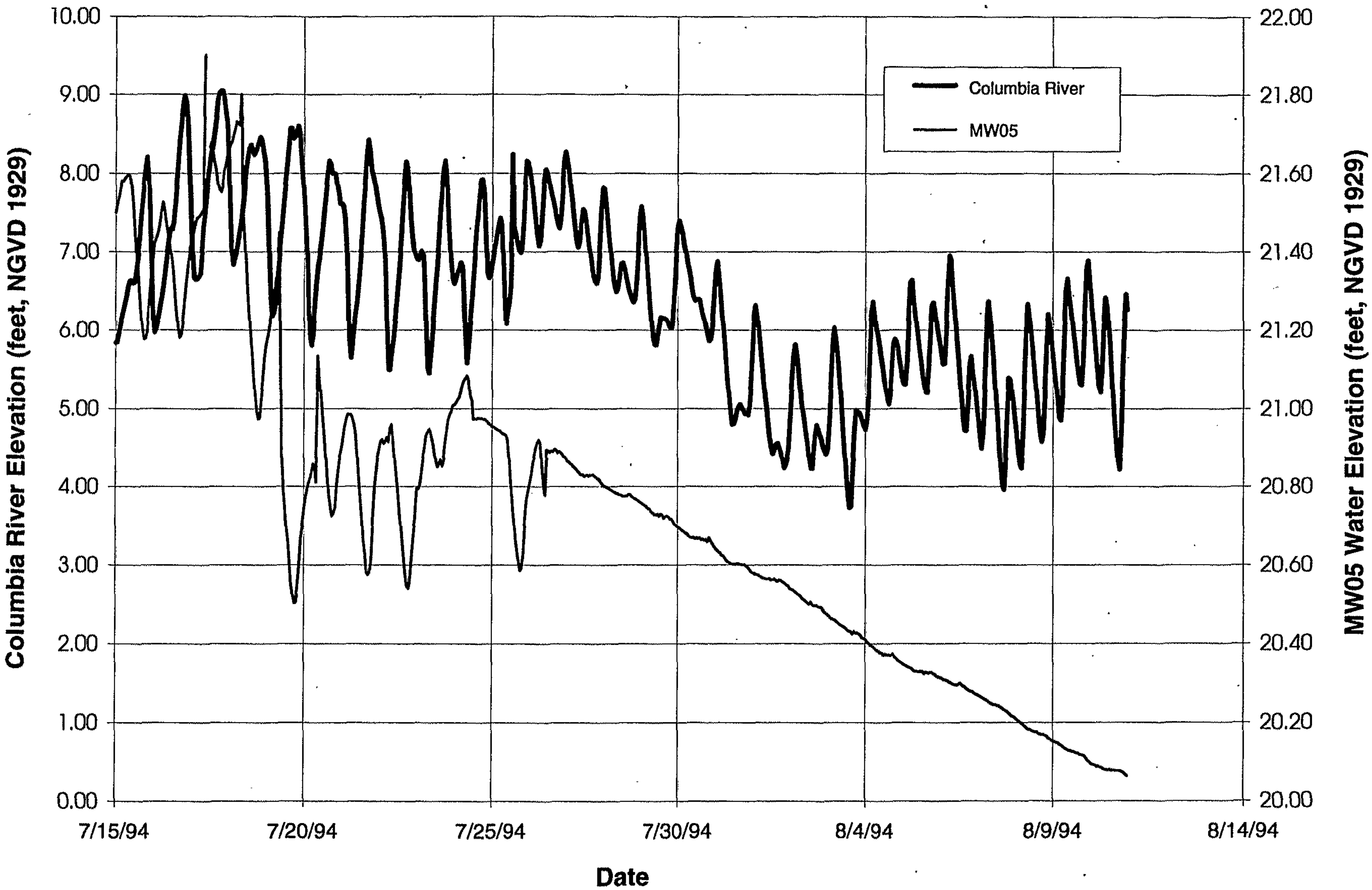


Figure 4-5
Columbia River and MW05 Hydrograph
Reynolds Metals Company
Troutdale, Oregon

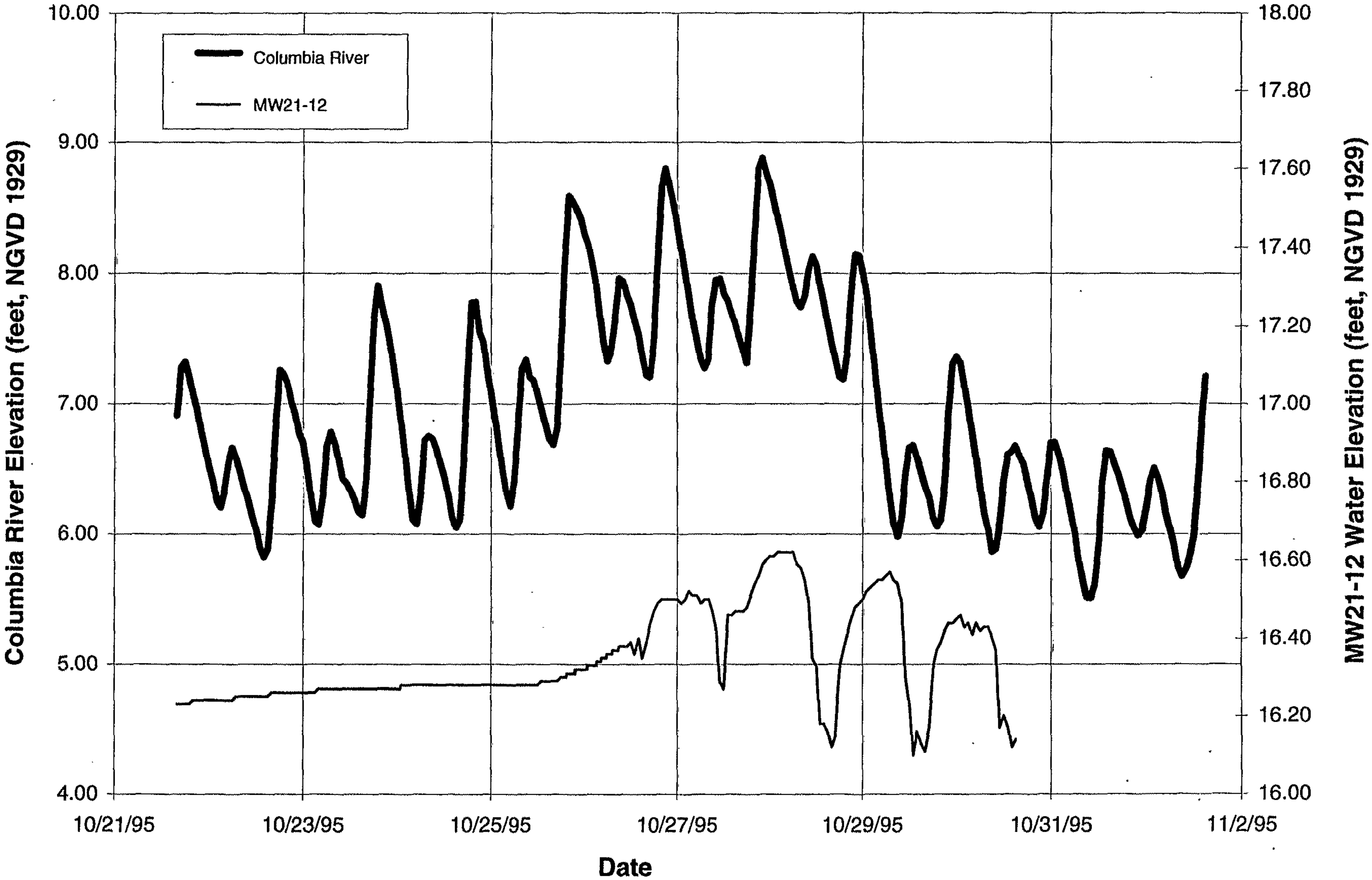


Figure 4-6
Columbia River and MW21-12 Hydrograph
Reynolds Metals Company·
Troutdale, Oregon

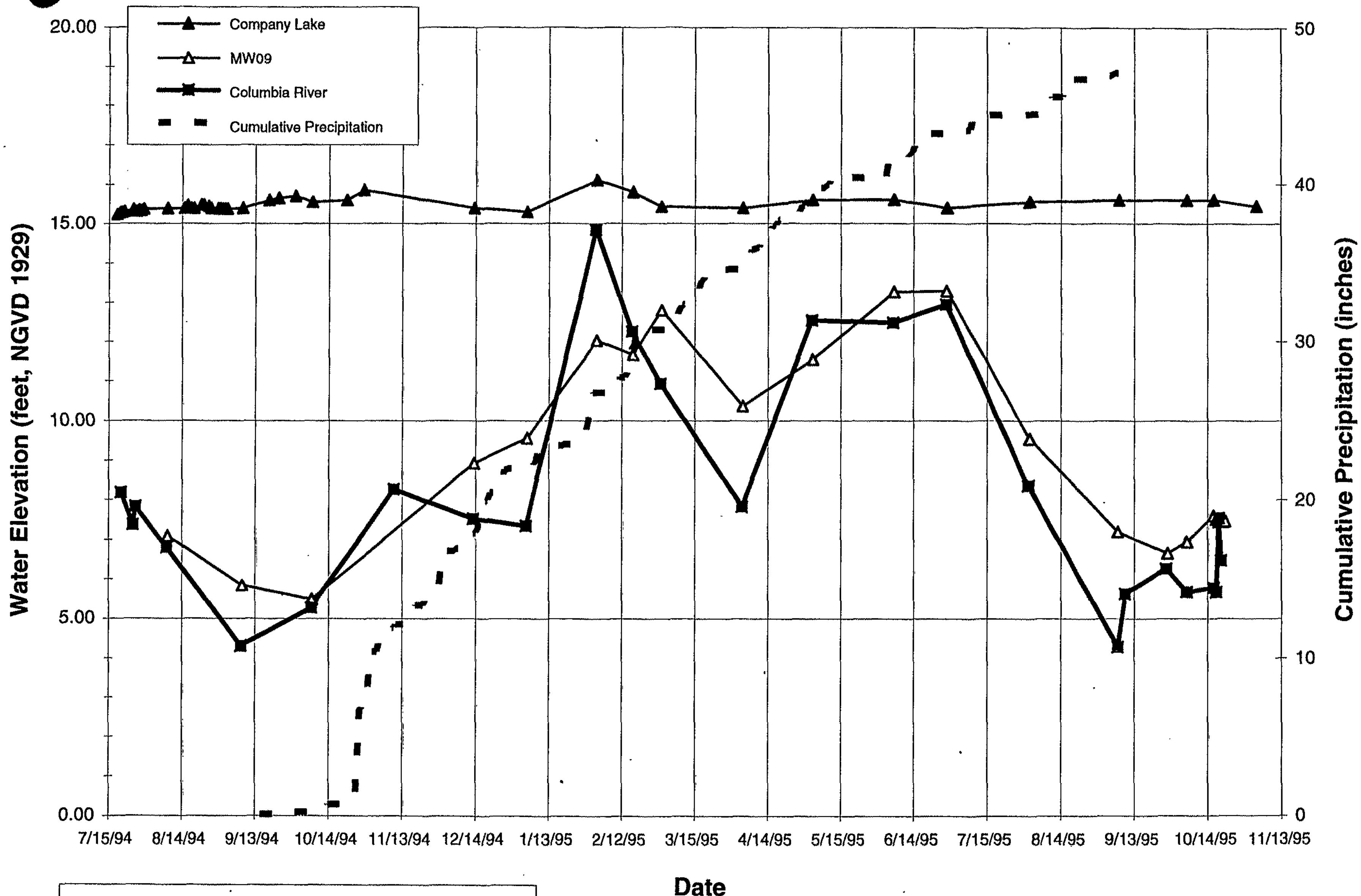
between the Sandy River stage and the measurements collected from the Columbia River measuring point (Table 4-2). Observations indicate that near the Sandy River's mouth, stage changes in the river are insignificant relative to stage changes in the Columbia, so that the Sandy rises and falls in conjunction with the Columbia. Wells MW05, MW07, MW10, and MW11 consistently show groundwater levels higher than the Sandy River, especially during the wet season (November 1994 through February 1995). These higher groundwater levels indicate northeasterly flow toward the Sandy River.

Table 4-2
Comparison of Columbia River and Sandy River Surface Water Levels
Reynolds Metals Company
Troutdale, Oregon

		Columbia River	Sandy River		
Date/Time		Elevation	Time	Elevation	Difference Between Sandy and Columbia River Levels
7/18/94	10:30	6.23	10:00	6.96	-0.73
7/19/94	10:30	7.18	11:05	7.29	-0.11
7/20/94	8:00	8.18	9:30	8.00	0.18
7/21/94	7:30	8.60	9:10	8.52	0.08
7/25/94	16:00	7.12	15:37	7.34	-0.22
7/26/94	9:00	7.88	8:35	7.82	0.06
7/27/94	10:00	7.54	10:10	7.70	-0.16
7/28/94	9:00	6.54	8:25	6.67	-0.13
7/29/94	9:00	5.81	8:44	6.18	-0.37

4.2.3 Company Lake

As discussed in Section 4.1, Company Lake receives inflow from numerous RMC processes. A weir currently exists at the outfall to the Columbia River, where the mass loading from Company Lake to the Columbia River is regulated by an existing NPDES permit. Company Lake water levels are compared with precipitation, water levels at MW09, and the Columbia River in Figure 4-7. Precipitation data were obtained from the closest available rain gauge (located in Gresham, Oregon). Company Lake surface water levels exhibit little seasonal variation, and they do not appear to reflect either Columbia River level or local shallow groundwater level fluctuations. Small variations in Company Lake levels appear to correspond to periods of high precipitation, which are also reflected in the river stage and water level data. Significant water level variations in Company Lake are not expected because of the fixed elevation of the outfall between Company Lake and the Columbia



Note: Precipitation data obtained from City of Portland Environmental Services. Gauge location: T1S, R3E, Section 4d; approximately 3-1/2 miles SW of RMC facility in Troutdale, Oregon.

Figure 4-7
Company Lake Elevations vs. MW09 Groundwater Elevations
Reynolds Metals Company
Troutdale, Oregon

River, and the relatively constant flow into the lake from the RMC facility. Monthly field observations of Company Lake levels between July 1994 and November 1995 range from approximately 15.24 feet in the summer to 16.10 feet in the winter. Company Lake elevations remained above MW09 groundwater levels for the time interval between July 1994 and the present. Figure 4-7 shows Company Lake elevations versus nearby MW09 shallow groundwater elevations. This figure shows that groundwater levels at MW09 respond primarily to Columbia River stage fluctuations and, to a lesser extent, to precipitation events. Because the elevation of Company Lake is controlled by a weir at the outfall ditch, and it receives relatively constant inflow from the plant, the lake elevation is not observed to vary in response to most groundwater or surface water elevation changes. However, when the Columbia River rises above elevation 20 feet (approximately), the river flows into the lake via the outfall ditch. If the river elevation remains above 20 feet for a sufficient period of time, the lake elevation will rise until it re-equilibrates with the river.

The degree of hydraulic connection between groundwater and Company Lake is not known; however, seasonal variations may cause the water table to rise in the winter above the base of the lake at its eastern boundary (Figure 4-1). Conversely, during the summer months, the water table near Company Lake appears to drop several feet below the base of the lake.

4.2.4 South Wetlands/Salmon Creek

Four monitoring wells (MW17-16, MW17-28, MW18-16, MW18-31) were installed at the perimeter of the south wetlands area during July 1995 to help assess vertical hydraulic gradients, the relationship between shallow groundwater and surface water, and constituent concentrations in the south wetlands area. Data will be collected at these locations through the 1995-96 wet season to evaluate seasonal surface water and shallow groundwater variability.

Staff gauges were installed in July and August 1995 in the vicinity of the south wetlands (Figure 4-1). Surface water measurements at staff gauge locations SG06 and SG07 indicated no presence of surface water (dry) for the duration of the monitoring period between July and November 1995 (Table 4-1). Figure 4-8 presents surface water and shallow groundwater elevations in the vicinity of the south wetlands area using data from staff gauge SG08 and well pair MW18-16 and MW18-31. No surface water was present at staff gauge locations SG06 and SG07 during the period of these observations. It is expected that surface water measurements will be collected at these locations during winter, spring, and early-summer conditions. SG08 elevations appear higher than groundwater levels at the MW18 well pair throughout the monitoring period. These data indicate that Salmon Creek, in the vicinity of MW18, may be recharging the shallow aquifer. Additional data will be collected to evaluate the persistence of this condition.

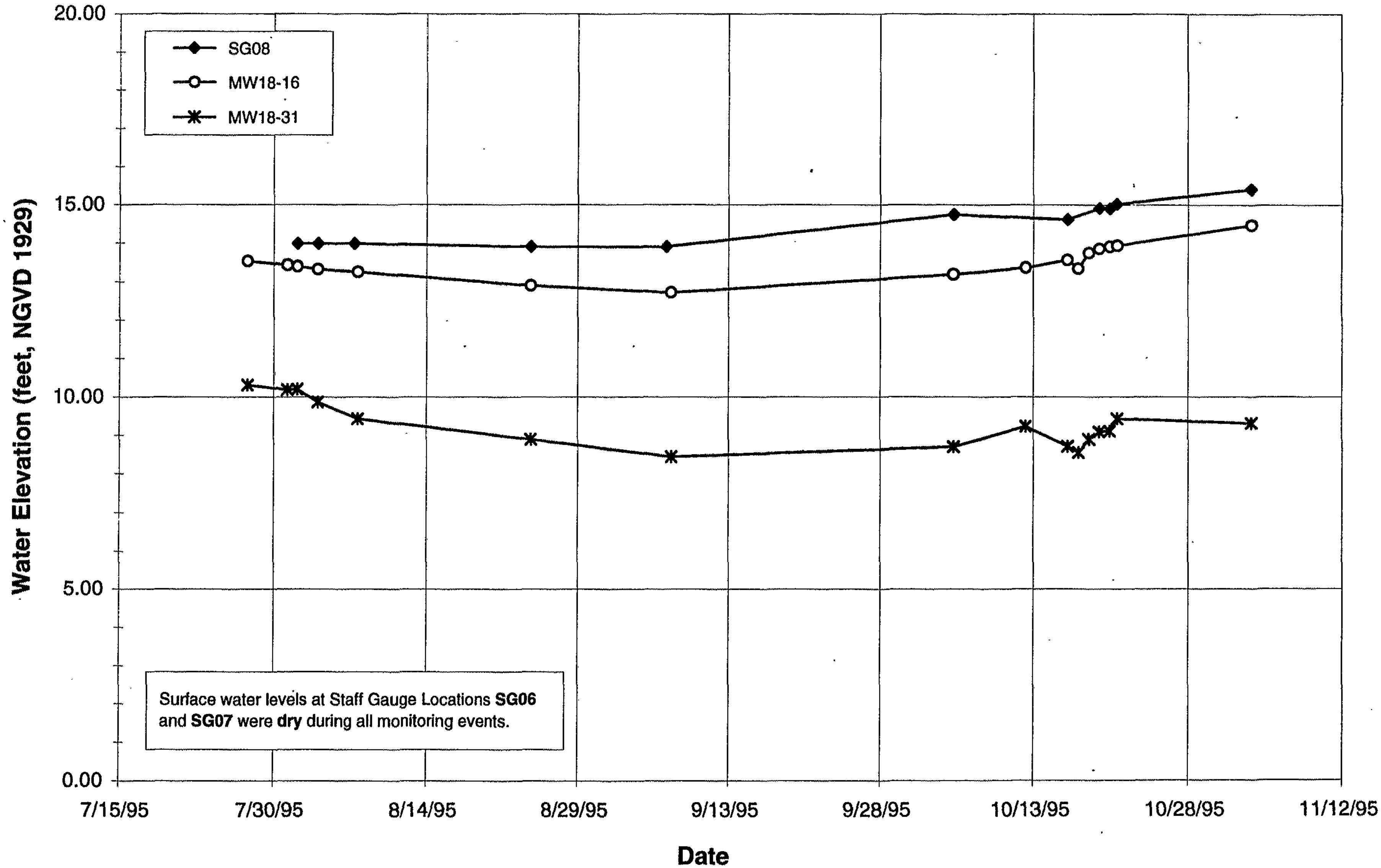


Figure 4-8
Salmon Creek Water Levels vs. MW18 Groundwater Levels
Reynolds Metals Company
Troutdale, Oregon

4.2.5 South Ditch

Water levels in the South Ditch are controlled by a pumping station. Water from RMC facility operations and stormwater runoff is collected at a pumping station near the southwestern corner of the plant and pumped north through an underground pipe into Company Lake.

The South Ditch originates in a topographic depression northeast of the plant area, just south of the dike. USGS topographic maps made in the 1950s and 1960s indicate a pond and intermittent stream at this location. Recent observations indicate that the pond fills during the winter months and is drained by the South Ditch.

The South Ditch has been dredged and straightened to carry surface water from the open area northeast of the plant site, along the eastern and southern fence lines, to the collection forebay near the southwestern corner of the plant. The South Ditch is the primary drainage feature at the RMC facility, receiving rainfall runoff, groundwater discharge, collected stormwater from the plant, groundwater discharged from a dewatering system, effluent from the sanitary wastewater treatment plant, and effluent from the process wastewater treatment plant. At its southwestern extent, the elevation of the surface water in the South Ditch is controlled by a water-level-activated pumping station, which is designed to prevent the water from rising above approximately 15 feet. The water removed from the ditch at the pumping station is discharged to Company Lake.

Shallow groundwater and surface water elevation data from staff gauges in the eastern portion of the South Ditch indicate that shallow groundwater is influenced by water levels in the ditch during wet portions of the year, when shallow groundwater elevations are above the base of the ditch. Figure 4-9 presents surface water elevations for staff gauges SG01 and SG02 and nearby monitoring well MW11 located near the eastern portion of South Ditch. During the wet season from February through May 1995, surface water at these two staff gauges fluctuated slightly above and below the shallow groundwater level at MW11. When water levels at MW11 are observed to be above the base of the ditch, surface water levels exhibit little variability. After the beginning of March 1995, when the MW11 groundwater elevation appeared to drop below the base of the ditch, the ditch levels began to drop until the base of the ditch was dry (June 1995). Between June and November 1995, groundwater elevations began to decline at MW11 from approximately 25 feet (early May) to 19 feet (early August). During this period, South Ditch gauge locations SG01 and SG02 were reported as "dry."

Shallow groundwater also appears to discharge into the South Ditch along its central portion, near SG04 and SG05. Figure 4-10 shows surface water elevations measured at staff gauge locations SG04 and SG05, and groundwater elevations at nearby monitoring wells MW01 and MW19. Shallow groundwater elevations were higher than surface water levels at these locations for the duration of the monitoring interval between July and November 1995, except at MW01, which appears to drop below the SG04 elevation during the late summer

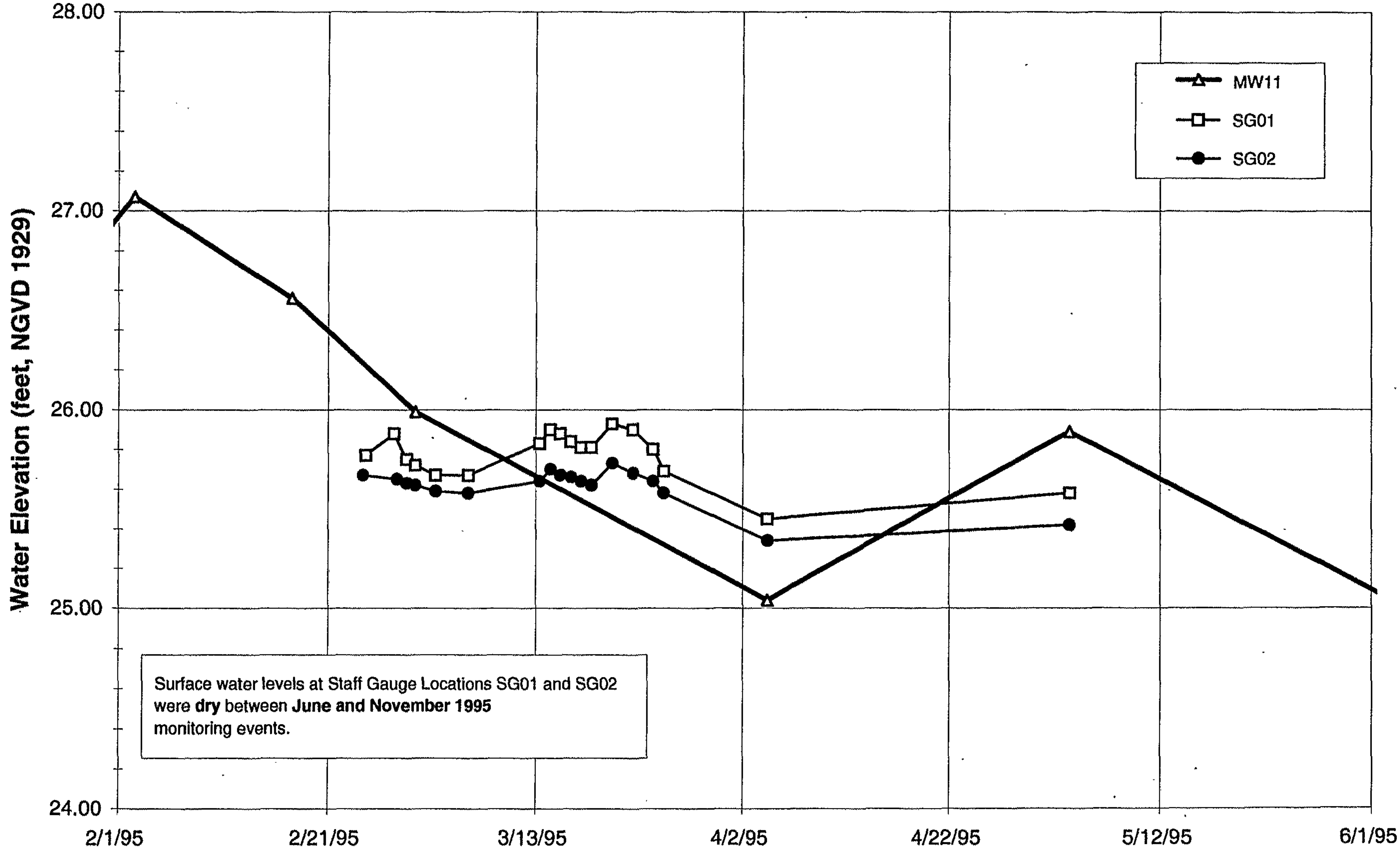


Figure 4-9
South Ditch Water Levels vs.
MW11 Groundwater Levels
Reynolds Metals Company
Troutdale, Oregon

J:\39293\grnd\watlev\WLMONTH.XLS\SG1_SG2 vs MW11

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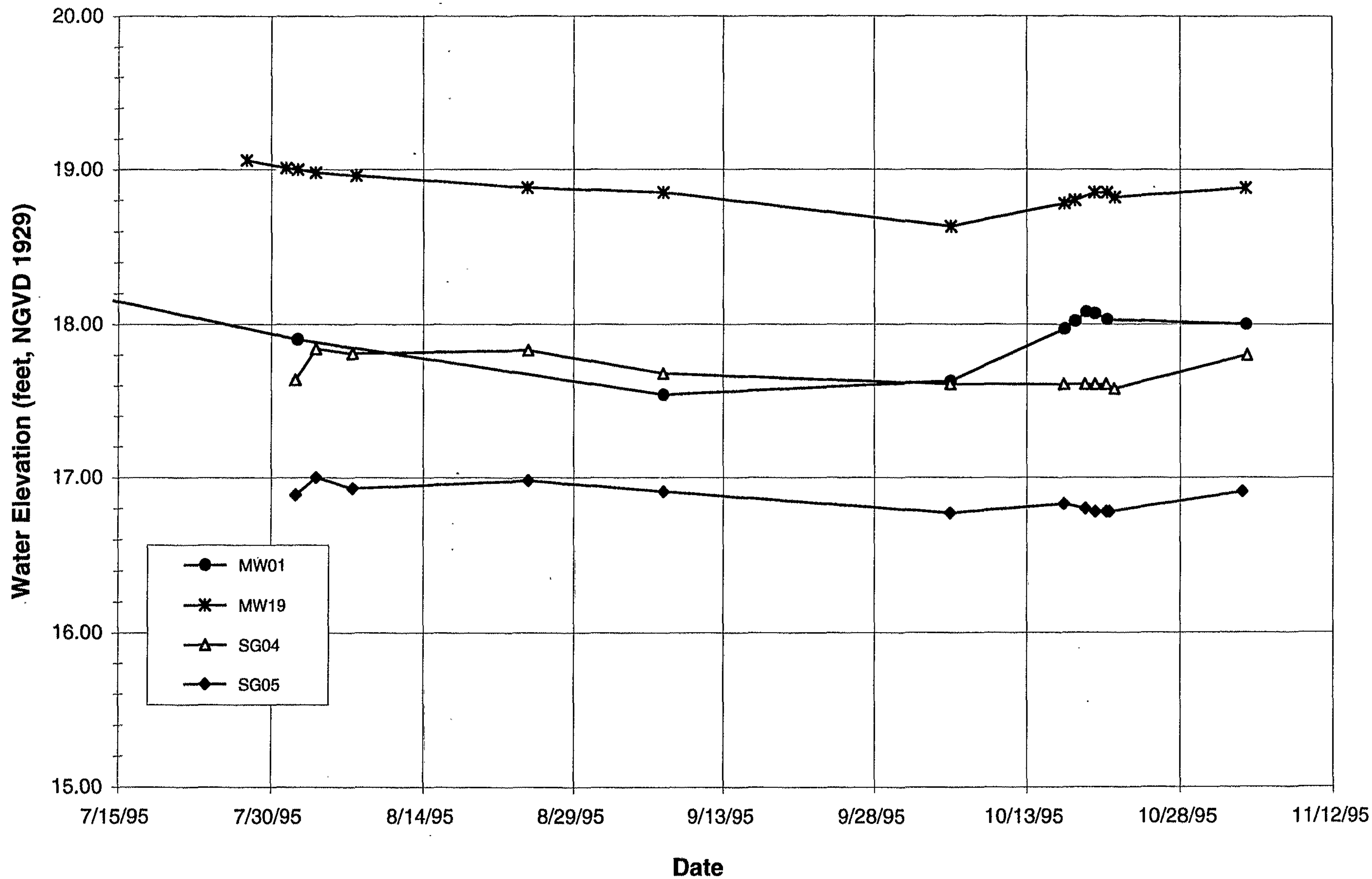


Figure 4-10
South Ditch Water Levels vs. MW01 and MW19 Groundwater Levels
Reynolds Metals Company
Troutdale, Oregon

months. This relationship suggests that shallow groundwater discharges into South Ditch for most of the year in this area. However, on the basis of the observations at MW01 and SG04, it is possible that the recharge to the ditch from discharged groundwater from the dewatering operation and other sources locally creates surface water elevations higher than nearby groundwater elevations in late summer months, causing surface water to temporarily recharge groundwater.

Figure 4-11 presents June 1995 hydrographs of shallow monitoring wells MW04 and MW12, and of the South Ditch near MW04. Water level data for the three hydrographs were collected using data loggers and pressure transducers. Water levels remained near 16 feet during this period, with observed water level fluctuations of generally less than 0.1 foot. Water levels in MW12 fluctuated at elevations between 14 and 15 feet for most of the period, with the magnitude of daily fluctuations approaching one foot. The hydrograph for the South Ditch shows water (elevations slightly less than those observed in MW12) fluctuations of generally between one-half and one foot. The frequent water level fluctuations in the South Ditch are caused by periodic pumping from the South Ditch pump station into Company Lake.

Water level fluctuations at MW12 generally follow the pumping fluctuations observed in the South Ditch, although the individual South Ditch water level peaks and troughs are muted and delayed 2 or 3 hours. No obvious correlation between Columbia River stage and MW12 water level fluctuations has been observed. However, because the magnitude of the water level response at MW12 is greater than the magnitude of South Ditch fluctuations, some hydraulic connection to the Columbia River is probable. Therefore, the MW12 water level fluctuations are probably the result of combined surface water fluctuations in the South Ditch and the Columbia River.

Examination of aerial photographs that pre-date the construction of the casthouse and potline 5 indicates that a portion of the south wetlands was present in the vicinity of MW04. This area was covered with pre-load material prior to the construction of potline 5. Well MW04 may have been installed through pre-load and fill into low-permeability sediment that has negligible hydraulic connection with the South Ditch, despite its proximity. Sediment data collected during the installation of MW04, and the low permeability of the sediment observed during well development and groundwater sampling, support the hypothesis that MW04 was installed in a backfilled portion of the south wetlands, and screened in fine-grained, wetlands-type sediment.

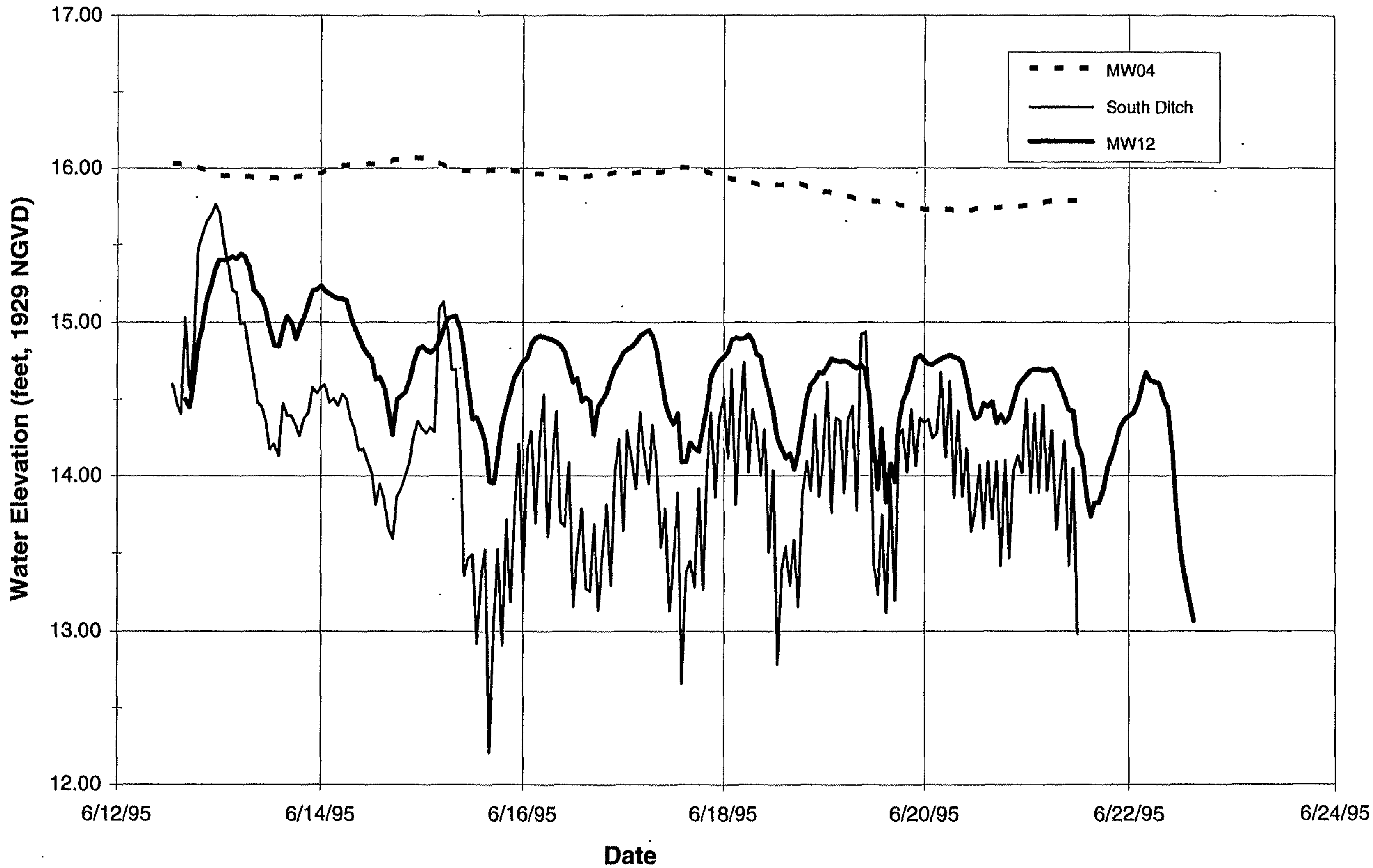


Figure 4-11
Hydrographs of MW04, MW12, and the South Ditch
Reynolds Metals Company
Troutdale, Oregon

SECTION 5

GROUNDWATER HYDROLOGY

Section 5
Groundwater Hydrology

An understanding of groundwater hydrology is necessary to assess the fate and advective transport of constituents from potential source areas. The following subsections provide an analysis and summary of water level data, horizontal and vertical hydraulic gradients, aquifer hydraulic conductivity, and groundwater flow velocities at the RMC site.

Water level data collected during the monitoring period of August 1994 to October 1995 were used to estimate horizontal and vertical hydraulic gradients and groundwater flow directions. Slug testing of shallow groundwater monitoring wells was used to estimate hydraulic conductivity. This information was combined and used to calculate shallow groundwater flow velocities at the site.

A single-well aquifer test (conducted in a deep irrigation well west of the site) was used to estimate deep aquifer transmissivity and help evaluate responses to deep aquifer pumping west of the facility. A multiple-well aquifer test (conducted using four of RMC's groundwater production wells) was used to help develop a better understanding of the deep aquifer flow system, as well as the interaction between the shallow and deeper portions of the aquifer, and to provide data that will support planned predictive analysis.

5.1 Groundwater Elevations and Flow Directions

Shallow groundwater generally flows from the southeast to the north-northwest toward the Columbia River across the RMC site. Shallow groundwater beneath the site is in hydraulic connection with the Columbia and Sandy Rivers, which are the primary controlling factors in groundwater elevation changes. The effect of surface water on shallow groundwater appears to diminish with distance from the rivers.

On the basis of water level data collected from monitoring wells MW01 through MW12 (installed in 1994) and the additional monitoring wells installed during summer 1995, the groundwater levels in the shallow sediments beneath the RMC facility range from approximately 2 to 27 feet bgs. The water levels at the RMC site are influenced by the variable permeability of shallow sediments, proximity to local surface water bodies (Columbia River, Sandy River, and South Ditch), local pumping of onsite production wells and sumps, and topographic features. Table 5-1 is a summary list of manually measured water levels collected from July 1994 through October 1995.

February 1995 and October 1995 water level measurements are presented to illustrate wet and dry season potentiometric surface contour maps based on water levels measured in shallow (<35 feet) monitoring wells installed at the RMC site. Water level measurements (in feet bgs) have been converted to elevation, and contoured in Figures 5-1 and 5-2. Groundwater elevations are in feet above mean sea level, relative to the 1929 National

Table 5-1
Groundwater Level Data Summary
Reynolds Metals Company
Troutdale, Oregon

	MW01		MW02-24		MW03		MW04		MW05		MW06		MW07		MW08		MW09	
GSE	*25.2*		*28.6*		*27.4*		*24.3*		*31.6*		*24.1*		*28.7*		*22.8*		*27.0*	
MPE	28.25		31.65		29.69		26.91		33.99		26.81		28.38		25.32		29.27	
Date	ELEV	DTW	ELEV	DTW	ELEV	DTW	ELEV	DTW	ELEV	DTW	ELEV	DTW	ELEV	DTW	ELEV	DTW	ELEV	DTW
7/20/94 8:00	17.68	10.57	11.09	20.56	22.41	7.28	8.98	17.93	20.81	13.18					8.18	17.14		
7/23/94 13:00	17.69	10.56	11.16	20.49	22.26	7.43	11.68	15.23	20.85	13.14					8.54	16.78		
7/25/94 12:00	17.70	10.55			22.22	7.47			20.81	13.18					8.68	16.64		
7/25/94 13:00							12.53	14.38	20.77	13.23					8.77	16.55		
7/25/94 15:00			11.01	20.64					20.67	13.32	9.99	16.82	14.60	13.78	7.98	17.34		
7/26/94 10:00	17.70	10.55	11.01	20.64	22.25	7.44	12.77	14.14	20.78	13.21	9.91	16.90	14.62	13.76	7.76	17.56		
8/8/94 13:00			10.31	21.34	21.93	7.76	12.28	14.63	20.18	13.82	8.36	18.45	13.94	14.44	5.85	19.47	7.09	22.18
9/8/94 15:00			8.63	23.02	21.56	8.13	10.65	16.26	19.09	14.90	7.53	19.28	12.25	16.13	4.97	20.35	5.84	23.43
10/7/94 10:00	18.12	10.13	7.53	24.12	20.90	8.79	9.83	17.08	17.14	16.85	6.61	20.20	9.02	19.36	4.12	21.20	5.49	23.78
11/10/94 12:00	19.88	8.37	12.44	19.21	25.03	4.66					9.91	16.90						
12/13/94 12:00	19.74	8.51	15.01	16.64	26.49	3.20	16.23	10.68	24.42	9.57	10.91	15.90	19.82	8.56	7.95	17.37	8.93	20.34
1/4/95 9:00	19.36	8.89	16.04	15.61	26.17	3.52	16.18	10.73	25.87	8.12	10.98	15.83	21.48	6.90	8.91	16.41	9.56	19.71
2/2/95 11:00	20.47	7.78	19.19	12.46	27.78	1.91							24.08	4.30	14.88	10.44	12.02	17.25
2/2/95 13:00	20.48	7.77	18.60	13.05			16.67	10.24	28.19	5.80								
2/17/95 12:00															11.86	13.46	11.66	17.61
2/17/95 14:00	19.99	8.26																
2/17/95 15:00									28.83	5.16								
2/17/95 16:00			17.11	14.54	27.85	1.84	16.17	10.74					23.81	4.57	11.95	13.37		
3/1/95 9:00	19.53	8.72	17.68	13.97			16.68	10.23	28.58	5.41			23.93	4.45	11.11	14.21		
3/1/95 10:00			17.68	13.97	26.69	3.00					13.88	12.93			11.12	14.20	12.80	16.47
4/4/95 9:00			15.26	16.39	26.08	3.61											10.37	18.90
4/4/95 10:00									28.08	5.91	11.32	15.49	21.93	6.45	8.11	17.21		
4/4/95 11:00	18.94	9.31					15.87	11.04										
4/5/95 8:00			15.19												8.34			
4/10/95 8:00			14.67												7.89			
4/15/95 8:00			15.22												10.06			
4/17/95 8:00			15.16												9.82			
4/25/95 8:00			14.97												9.14			
5/3/95 8:00																		
5/3/95 10:00	19.30	8.95	15.97	15.68	26.84	2.85	16.38	10.53	28.55	5.44	13.48	13.33	21.92	6.46			11.54	17.73
5/5/95 8:00															11.89			
5/10/95 8:00															12.19			
5/23/95 8:00			16.59												12.20			
6/1/95 8:00			16.43												13.04			
6/5/95 8:00			16.24	15.41				26.91							12.91	12.41		
6/6/95 8:00															12.34	12.98		
6/6/95 12:00	18.50	9.75			25.69	4.00	15.74	11.17	26.57	7.42	13.89	12.92	20.80	7.58			13.27	16.00
6/28/95 10:00	18.38	9.87	15.82	15.83	24.40	5.29	15.88	11.03	25.81	8.18	13.85	12.96	20.36	8.02	12.97	12.35	13.29	15.98
7/27/95 13:05																		
7/31/95 11:15																		
8/1/95 14:27	17.90	10.35					14.16	12.75	24.12	9.87	10.30	16.51	18.58	9.80	8.67	16.65	9.54	19.73
8/3/95 9:05																		
8/7/95 9:00			11.86	19.79														
8/24/95 8:30			11.08	20.57	23.02	6.67												
9/7/95 0:00	17.54	10.71	10.56	21.09	23.09	6.60	12.25	14.66	22.09	11.90	8.07	18.74	15.99	12.39	5.83	19.49	7.20	22.07
9/10/95 9:50																		
9/27/95 13:55																	6.66	22.61
10/5/95 13:30	17.63	10.62															6.95	22.32
10/16/95 17:45	17.97	10.28															7.60	21.67
10/17/95 18:00	18.02	10.23															7.51	21.76
10/18/95 19:45	18.08	10.17															7.45	21.82
10/19/95 15:25	18.07	10.18															7.45	21.82

Notes:
GSE = Ground surface elevation (feet, 1929 NGVD).
MPE = Measuring Point Elevation (feet, 1929 NGVD), corresponding to top of PVC well casing.
DTW = Depth to groundwater (feet below ground surface).
ELEV = Groundwater elevation (feet, NGVD). Groundwater elevation = MPE - DTW.

Table 5-1 (continued)
Groundwater Level Data Summary
Reynolds Metals Company
Troutdale, Oregon

	MW10		MW11		MW12		MW13		MW14		MW15		MW16		MW17-16		MW17-28	
GSE		27.9		29.5		20.2		28.3		28.3		20.9		26.7		24.8		24.8
MPE		30.28		31.61		22.53		30.88		30.88		22.75		28.91		27.13		27.30
Date	ELEV	DTW	ELEV	DTW	ELEV	DTW	ELEV	DTW	ELEV	DTW	ELEV	DTW	ELEV	DTW	ELEV	DTW	ELEV	DTW
7/20/94 8:00																		
7/23/94 13:00																		
7/25/94 12:00																		
7/25/94 13:00																		
7/25/94 15:00																		
7/26/94 10:00																		
8/8/94 13:00	17.48	12.80	18.39	13.22	11.31	11.22												
9/8/94 15:00	12.78	17.50	17.40	14.21	10.37	12.16												
10/7/94 10:00	11.89	18.39	16.29	15.32	10.11	12.42												
11/10/94 12:00																		
12/13/94 12:00	14.94	15.34	24.92	6.69	14.11	8.42												
1/4/95 9:00	20.55	9.73	25.20	6.41	13.86	8.67												
2/2/95 11:00																		
2/2/95 13:00	24.98	5.30	27.07	4.54	16.04	6.49												
2/17/95 12:00																		
2/17/95 14:00																		
2/17/95 15:00	27.15	3.13	26.56	5.05														
2/17/95 16:00	27.10	3.18			15.69	6.84												
3/1/95 9:00	24.80	5.48	25.99	5.62	14.74	7.79												
3/1/95 10:00	24.80	5.49																
4/4/95 9:00	22.17	8.11																
4/4/95 10:00			25.04	6.57														
4/4/95 11:00					13.85	8.68												
4/5/95 8:00	22.08																	
4/10/95 8:00	21.90																	
4/15/95 8:00	22.98																	
4/17/95 8:00	22.56																	
4/25/95 8:00	21.86																	
5/3/95 8:00	22.80	7.48																
5/3/95 10:00			25.89	5.72	14.81	7.72												
5/5/95 8:00	22.51																	
5/10/95 8:00	22.15																	
5/23/95 8:00	21.43																	
6/1/95 8:00	20.81																	
6/5/95 8:00	20.50	9.78																
6/6/95 8:00																		
6/6/95 12:00			24.94	6.67	14.44	8.09												
6/28/95 10:00	19.71	10.57	24.31	7.30	14.28	8.25												
7/27/95 13:05							13.01	17.87	23.19	7.69	12.57	10.18	20.72	8.19	13.88	13.25	13.93	13.37
7/31/95 11:15							12.73	18.15	23.15	7.73	12.46	10.29	20.64	8.27	13.72	13.41	13.69	13.61
8/1/95 14:27	17.04	13.24	22.43	9.18	12.82	9.71	12.63	18.25	23.08	7.80	12.44	10.31	20.62	8.29	13.23	13.90	13.63	13.67
8/3/95 9:05							12.49	18.39	23.02	7.86	12.34	10.41	20.60	8.31	13.46	13.67	13.45	13.85
8/7/95 9:00							12.13	18.75	22.92	7.96	12.09	10.66	20.53	8.38	13.29	13.84	13.26	14.04
8/24/95 8:30							11.04	19.84	22.52	8.36			20.33	8.58	12.74	14.39	12.70	14.60
9/7/95 0:00	14.68	15.60	19.73	11.88	11.95	10.58	10.36	20.52	22.22	8.66	11.89	10.86	20.19	8.72	12.44	14.69	12.52	14.78
9/10/95 9:50																		
9/27/95 13:55																		
10/5/95 13:30			18.60	13.01														
10/16/95 17:45			20.85	10.76														
10/17/95 18:00			20.87	10.74														
10/18/95 19:45			20.76	10.85														
10/19/95 15:25			21.14	10.47														

Notes:

Notes: GSE = Ground surface elevation (feet, 1929 NGVD).
MPE = Measuring Point Elevation (feet, 1929 NGVD), corresponding to top of PVC well casing.
DTW = Depth to groundwater (feet below ground surface).
ELEV = Groundwater elevation (feet, NGVD). Groundwater elevation = MPE - DTW.

Table 5-1 (Continued)
Groundwater Level Data Summary
Reynolds Metals Company
Troutdale, Oregon

	MW18-16		MW18-31		MW19		MW20		MW21-25		MW22		Columbia River		PW06	
GSE		*21.5*		*21.5*		*24.8*		*25.8*		*22.0*		*22.6*				
MPE		23.98		23.95		27.10		28.47		24.60		25.35		32.63		31.28
Date	ELEV	DTW	ELEV	DTW	ELEV	DTW	ELEV	DTW	ELEV	DTW	ELEV	DTW	ELEV	DTW	ELEV	DTW
7/20/94 8:00													6.61			
7/23/94 13:00													6.90			
7/25/94 12:00													6.58			
7/25/94 13:00													8.24			
7/25/94 15:00													7.23			
7/26/94 10:00													8.05			
8/8/94 13:00													5.35		9.22	22.06
9/8/94 15:00													4.25		11.06	20.22
10/7/94 10:00													5.33		4.07	27.21
11/10/94 12:00													7.18			
12/13/94 12:00													7.99		8.13	23.15
1/4/95 9:00															8.03	23.25
2/2/95 11:00																
2/2/95 13:00															12.26	19.03
2/17/95 12:00													13.05			
2/17/95 14:00													13.56			
2/17/95 15:00													13.52			
2/17/95 16:00													13.49		11.72	19.56
3/1/95 9:00													12.32		11.79	19.49
3/1/95 10:00													12.33		11.21	20.07
4/4/95 9:00															8.69	22.59
4/4/95 10:00													9.47		8.25	23.03
4/4/95 11:00																
4/5/95 8:00													9.12		7.75	
4/10/95 8:00													9.35		6.25	
4/15/95 8:00													12.14		6.76	
4/17/95 8:00													11.52		6.65	
4/25/95 8:00													10.98		9.06	
5/3/95 8:00													13.86		7.74	23.54
5/3/95 10:00																
5/5/95 8:00													13.57		7.65	
5/10/95 8:00													13.69		7.82	
5/23/95 8:00													13.86		10.69	
6/1/95 8:00													14.60		10.55	
6/5/95 8:00													14.12			
6/6/95 8:00															7.20	24.08
6/6/95 12:00																
6/28/95 10:00													14.25		7.57	23.71
7/27/95 13:05	13.53	10.45	10.31	13.64	19.06	8.04										
7/31/95 11:15	13.43	10.55	10.19	13.76	19.01	8.09										
8/1/95 14:27	13.39	10.59	10.20	13.75	19.00	8.10							9.65	22.98	5.13	26.15
8/3/95 9:05	13.32	10.66	9.87	14.08	18.98	8.12									4.41	26.87
8/7/95 9:00	13.25	10.73	9.43	14.52	18.96	8.14										
8/24/95 8:30	12.90	11.08	8.89	15.06	18.88	8.22										
9/7/95 0:00	12.72	11.26	8.44	15.51	18.85	8.25	8.10	20.37	7.19	17.41	7.72	17.63	4.29	28.34	6.09	25.19
9/10/95 9:50													5.63	27.00	3.02	28.26
9/27/95 13:55													6.27	26.36		
10/5/95 13:30					18.63	8.47							5.68	26.95		
10/16/95 17:45					18.78	8.32							5.78	26.85		
10/17/95 18:00					18.80	8.30							5.67	26.96		
10/18/95 19:45													7.54	25.09		
10/19/95 15:25					18.85	8.25							6.48	26.15		

Notes:

Notes: GSE = Ground surface elevation (feet, 1929 NGVD).
MPE = Measuring Point Elevation (feet, 1929 NGVD), corresponding to top of PVC well casing.
DTW = Depth to groundwater (feet below ground surface).
ELEV = Groundwater elevation (feet, NGVD). Groundwater elevation = MPE - DTW.

JDP 9293SG5A.DWG
13-Dec-1995

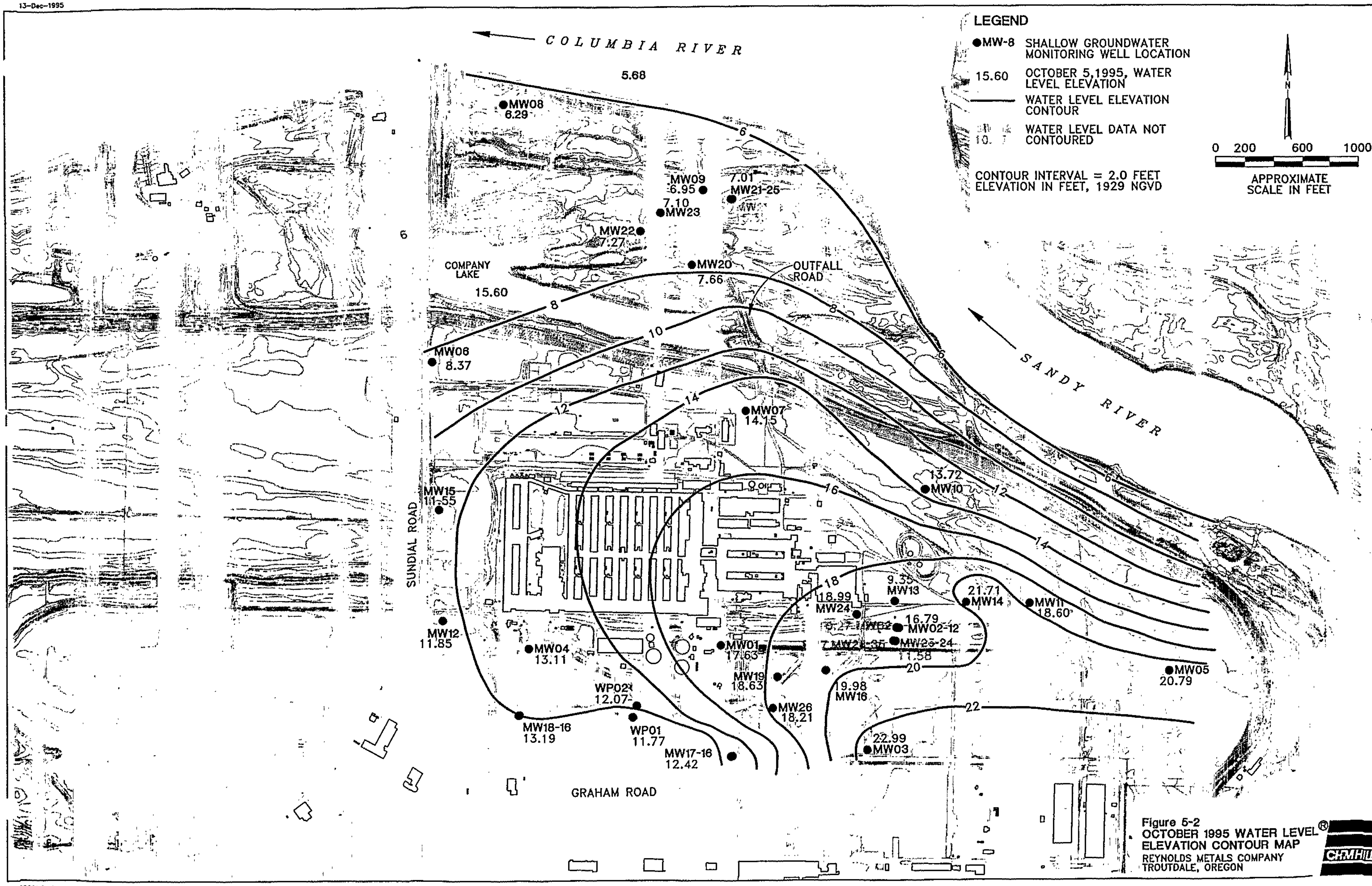


Figure 5-2
OCTOBER 1995 WATER LEVEL ELEVATION CONTOUR MAP
REYNOLDS METALS COMPANY
TROUTDALE, OREGON

CH2MHILL

9293SG5A.DWG

XP 9293W13A.DWG
21-NOV-1995

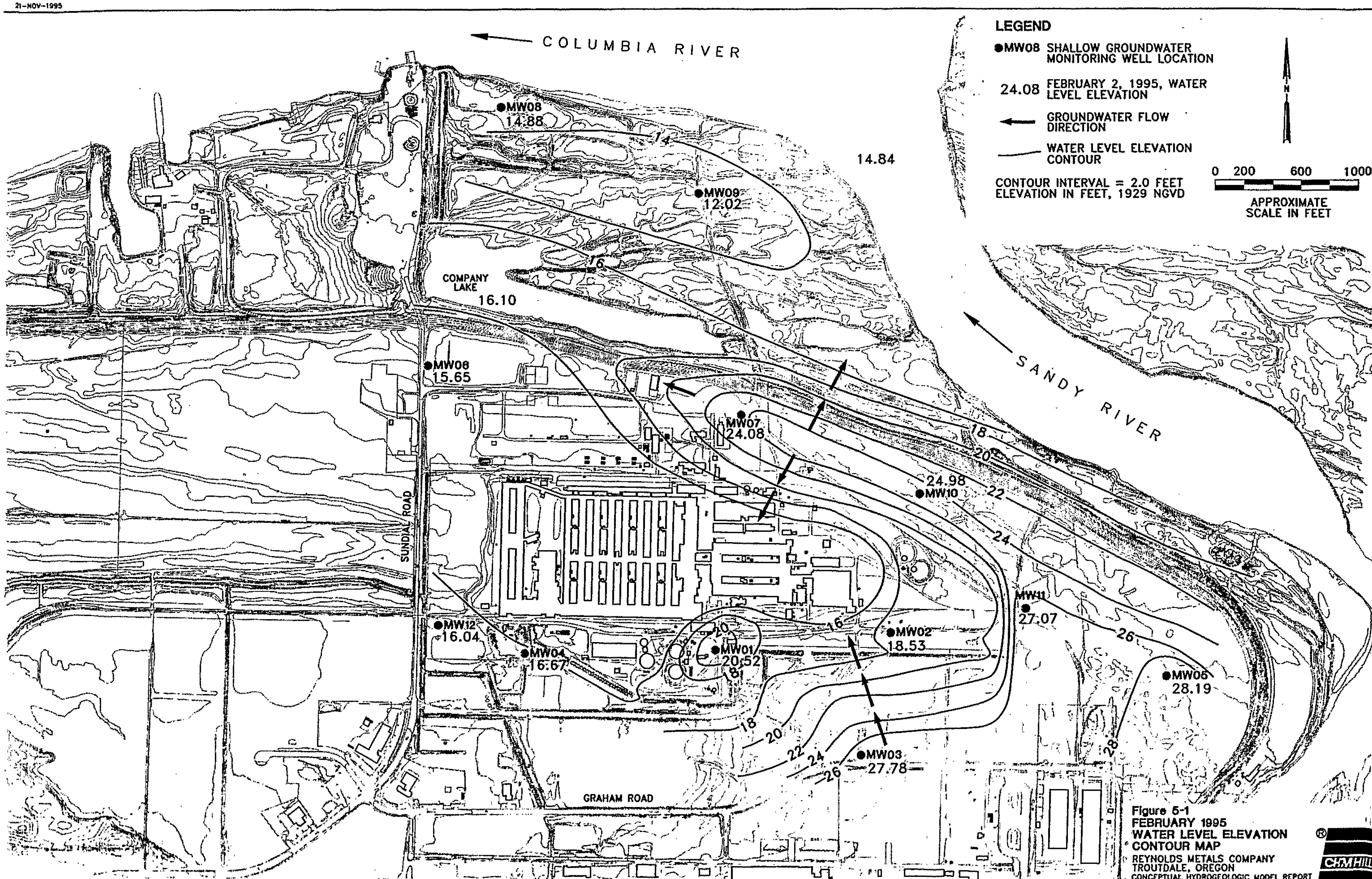


Figure 5-1
FEBRUARY 1995
WATER LEVEL ELEVATION
CONTOUR MAP
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
CONCEPTUAL HYDROGEOLOGIC MODEL REPORT

CH2M HILL

Geodetic Vertical Datum (NGVD). Groundwater elevation contour maps for October 1994 and May 1995 are presented in CH2M HILL, 1995e.

Groundwater elevations typical of wet season (winter) conditions are illustrated by the contours of the February 1995 elevation data presented in Figure 5-1. Winter water level elevations generally range from 12 feet (MW09) to 28 feet (MW05), and groundwater generally flows from south to north across the site. Variations in that generalized flow pattern occur at the following locations:

- **Near the Sandy and Columbia Rivers.** Although groundwater levels near the rivers vary with river stage fluctuations, groundwater flow near the Sandy and the Columbia Rivers appears to be directly toward the surface water bodies that have stage elevations that are generally lower than nearby groundwater. As groundwater approaches the Sandy River, which runs southeast to northwest east of the site, the flow direction deflects from the north to the northeast. During high river stage conditions the river was observed to briefly rise to elevations slightly higher than groundwater levels at MW08 and MW09. These conditions are of short duration and the net groundwater flow direction at the site is toward the rivers. In Figure 5-1, which presents February 1995 water levels, the Columbia River is seen to be very close to the elevation at MW08, and slightly higher than the elevation at MW09, resulting in an apparent gradient reversal near the river.

- **Dike Area Mound.** Groundwater forms a mound or ridge along the south side of the dike in the area between MW11 and MW07. On the basis of observations made during drilling and groundwater monitoring, the mound is probably the result of a topographic depression that concentrates surface water and, therefore, recharge in this area during wetter months. The mounding is further enhanced by the presence of a low-permeability layer beneath the topographic depression; this layer restricts vertical groundwater flow. As a result, groundwater flows from this area to the north-northeast toward the Sandy River, northwest toward Company Lake, and locally to the west or southwest into the scrap yard.

- **South Ditch in Scrap Yard Area.** Groundwater elevation contours are drawn slightly deflected as they cross the South Ditch. The deflection is intended to reflect groundwater discharge to the ditch, based on lower observed ditch water levels than in nearby monitoring wells.

- **MW01.** Water level elevations at MW01 are consistently higher than expected based on nearby water level elevations and gradients. The cause of the elevated water levels at this location is unknown.

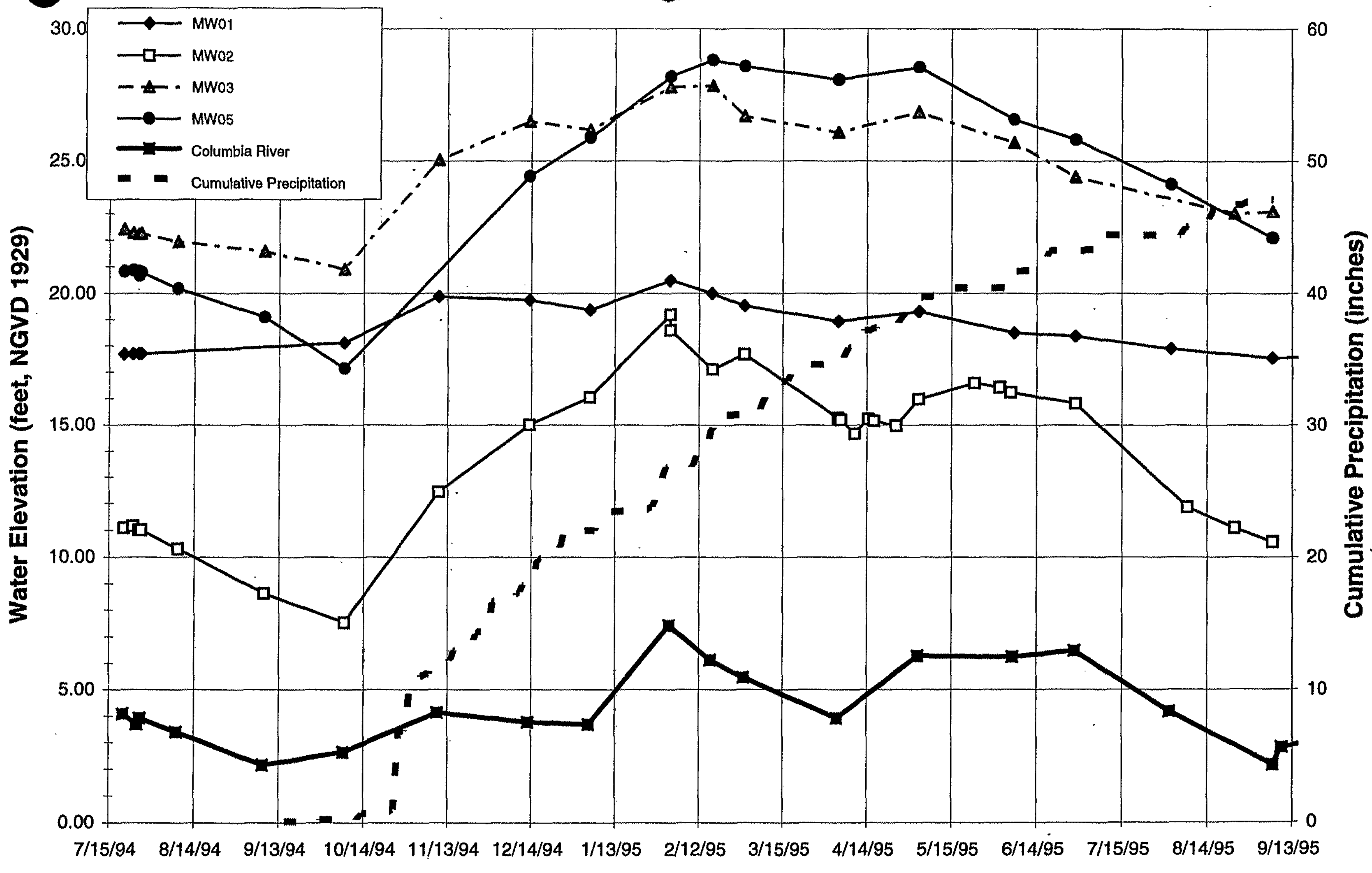
- **Bakehouse.** Ongoing dewatering in and around the bakehouse (the first building northeast of MW01) has created an elongate depression in the water table surface, running between MW02 and MW06.

- **Company Lake**. Groundwater elevations southeast of Company Lake (at MW07) are substantially higher than the Company Lake elevation. Groundwater elevations north and southwest of Company Lake are similar in elevation to Company Lake. These data suggest that groundwater discharges to Company Lake during high water conditions.

Water level elevations typical of late summer, or dry season, conditions are contoured in Figure 5-2. This map includes monitoring wells, and two of the temporary monitoring wells (WP01 and WP02), that were installed in August and September 1995. Not all of the water elevations measured on October 5 were contoured in Figure 5-2. At several locations, well-pairs (two adjacent wells with different screened interval elevations) were installed to evaluate vertical gradients and constituent concentrations. Because vertical gradients can cause groundwater elevations to vary with depth, only wells that appear to represent first encountered groundwater elevations (based on observations made while drilling) have been contoured (except MW02-12, which appears to exhibit an anomalously low elevation). The lowered water level elevations, diminished recharge due to precipitation, and improved resolution resulting from the new well installations led to the following notable differences from the contours shown in Figure 5-1:

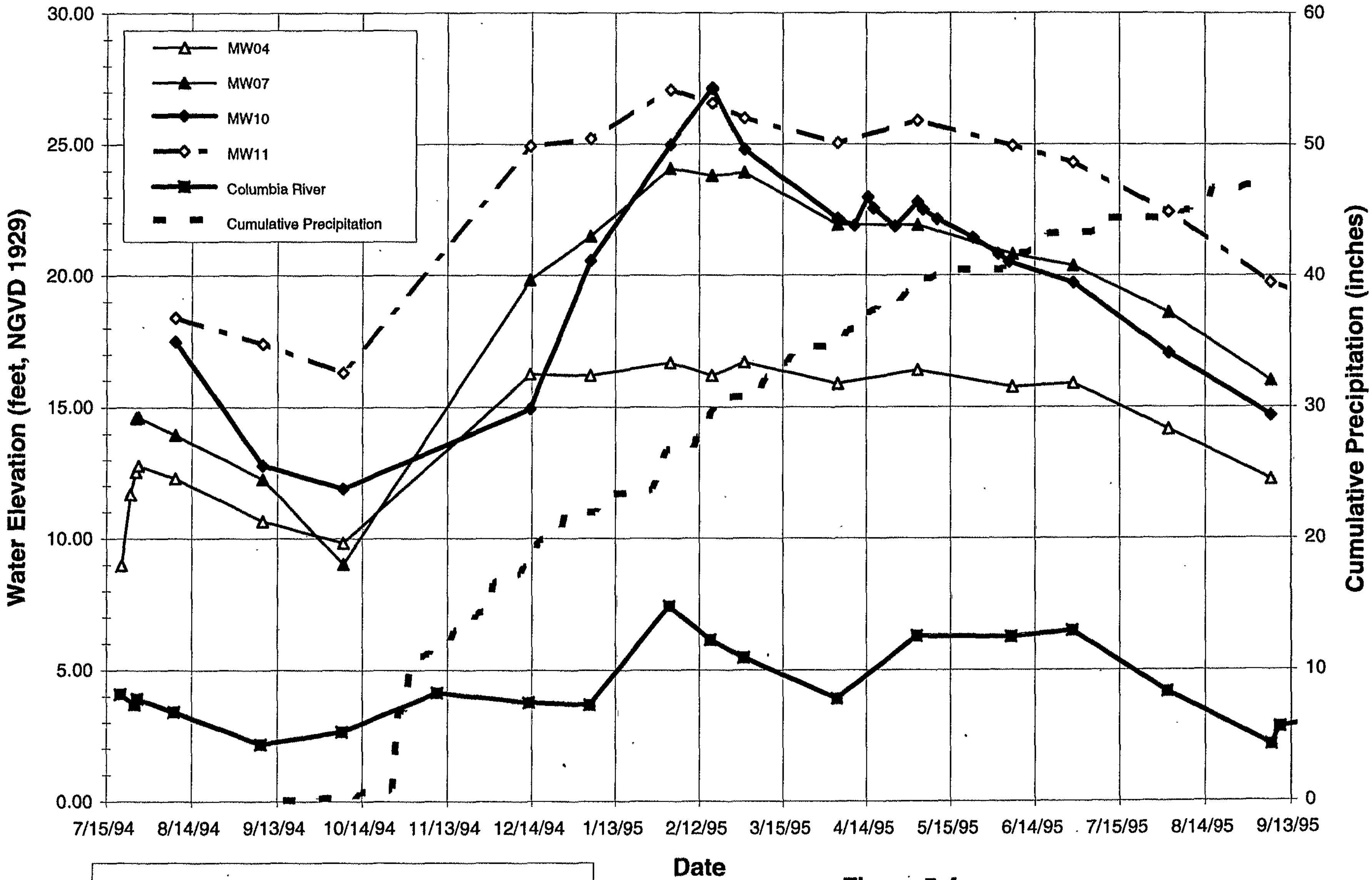
- No gradient reversal near the Columbia River is apparent.
- No elongate ridge is observed south of the dike between MW11 and MW10.
- The effects of dewatering in the vicinity of the bakehouse are not apparent.
- The mound in the vicinity of MW01 appears diminished.
- Groundwater between MW03 and the MW17 well pair flows primarily east to west, rather than south to north.
- Water levels in Company Lake are substantially higher than groundwater elevations both north and south of the lake. If Company Lake is assumed to average 3 feet deep at its western end, then the groundwater elevations are below the lake bed.

Hydrographs comparing water elevations for wells installed in 1994 (MW01 through MW12), cumulative precipitation, and the Columbia River for July 1994 through September 1995 are presented in Figures 5-3, 5-4, and 5-5. Figure 5-3 compares groundwater elevations at MW01, MW02, MW03, and MW05 with Columbia River stage (elevation) and cumulative precipitation. In general, water levels declined until the rate of precipitation increased in October and November 1994. However, the increased rate of groundwater elevation rise in late 1994 was coincident with a rising trend in the Columbia River stage. After January 1995, rising groundwater trends due to precipitation appeared to stabilize, and groundwater appeared to respond primarily to Columbia River stage fluctuations; groundwater levels declined with the Columbia River stage in February and March 1995, and again in June through September 1995, even though cumulative precipitation continued



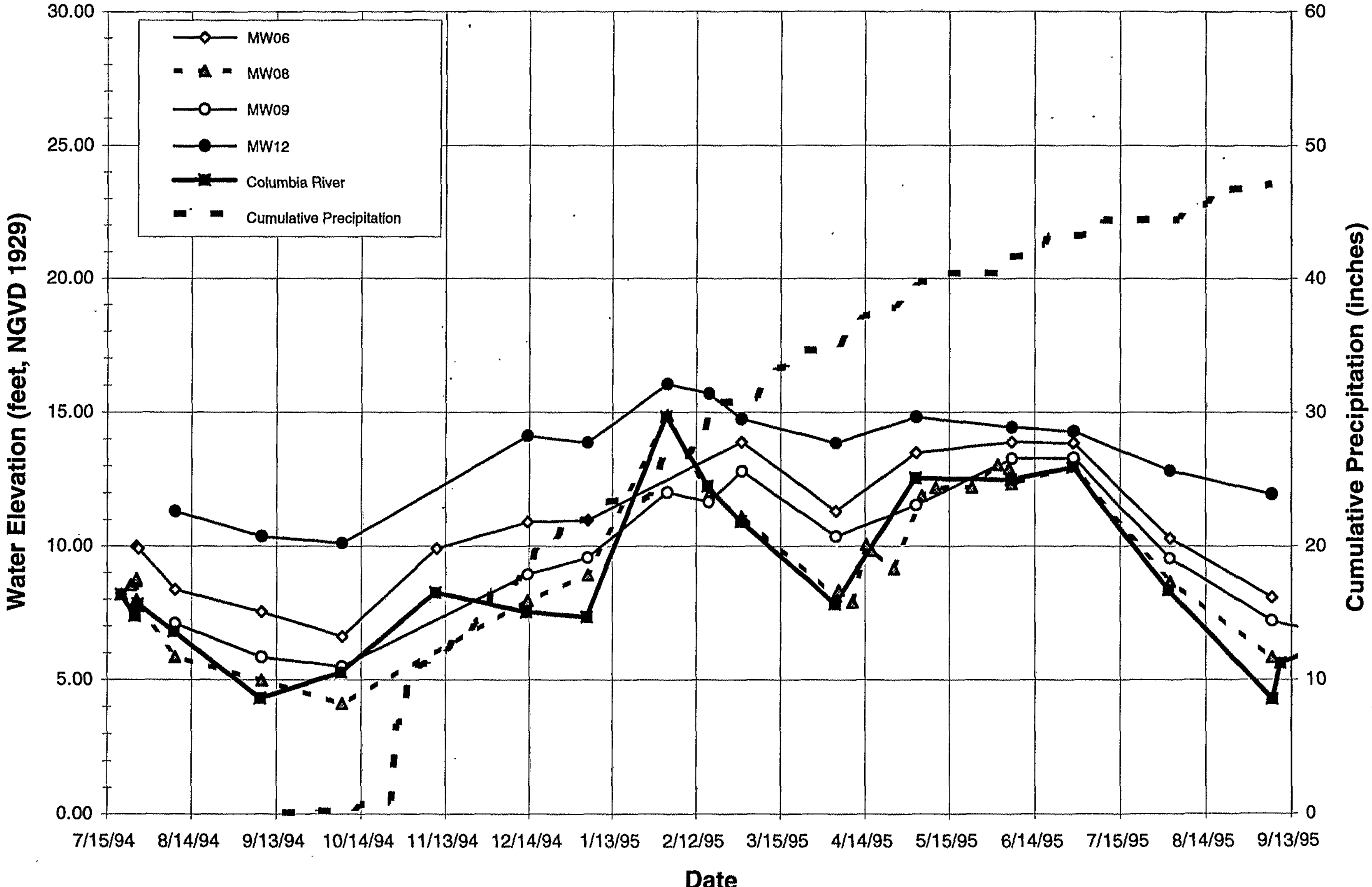
Note: Precipitation data obtained from City of Portland Environmental Services. Gauge location: T1S, R3E, Section 4d; approximately 3-1/2 miles SW of RMC facility in Gresham, Oregon.

Figure 5-3
1994 - 1995 Groundwater and Columbia River Levels (Wells MW01, MW02, MW03, MW05)
Reynolds Metals Company
Troutdale, Oregon



Note: Precipitation data obtained from City of Portland Environmental Services. Gauge location: T1S, R3E, Section 4d; approximately 3-1/2 miles SW of RMC facility in Gresham, Oregon.

Figure 5-4
1994 - 1995 Groundwater and Columbia River Levels (Wells MW04, MW07, MW10, MW11)
Reynolds Metals Company
Troutdale, Oregon



Note: Precipitation data obtained from City of Portland Environmental Services. Gauge location: T1S, R3E, Section 4d; approximately 3-1/2 miles SW of RMC facility in Gresham, Oregon.

Figure 5-5
1994 - 1995 Groundwater and Columbia River Levels (Wells MW06, MW08, MW09, MW12)
Reynolds Metals Company
Troutdale, Oregon

to increase. These data suggest groundwater beneath the site is in hydraulic connection with the Columbia and Sandy Rivers, which are the primary controlling factors in groundwater elevation changes. The groundwater elevation response to river stage at MW03, which is farther from the Columbia and Sandy Rivers, was less than that at the other monitoring wells. This difference suggests that the effect of surface water on shallow groundwater levels diminishes with distance from the rivers. The water level response at MW01 was also muted relative to other wells, possibly because water levels at MW01 are controlled primarily by unknown conditions which result in the apparent mound at that location.

Figure 5-4 compares groundwater elevations at MW04, MW07, MW10, and MW11 with Columbia River stage (elevation) and cumulative precipitation. In general, the relationships among water levels, surface water, and precipitation illustrated in Figure 5-3 are observed in Figure 5-4 as well. Water levels at MW07 and MW10 are shown to increase at a greater rate than the rise in river stage, probably as a result of increased surface water infiltration from the topographic depression that collects surface water south of the dike in that area. MW04 also had a muted response, probably because it is completed in a fine-grained sequence adjacent to the South Ditch pumping station, which is held by pumping at a relatively constant elevation of approximately 15 feet NGVD.

Figure 5-5 compares groundwater elevations at MW06, MW08, MW09, and MW12 with Columbia River (elevation) and cumulative precipitation. In general, these wells exhibited the relationships among groundwater levels, surface water levels, and precipitation shown in Figure 5-3 and 5-4. After about January 1995, groundwater levels responded primarily to river stage fluctuations. Groundwater elevations in these wells appeared to respond more rapidly to river stage fluctuations than did wells located farther to the south.

Recharge to the shallow aquifer is expected to result primarily from infiltration of precipitation. The primary discharge areas for shallow groundwater include the Columbia River to the north and the Sandy River to the east. Locally, minor groundwater discharge (and possibly recharge) is likely to occur beneath Company Lake, along the South Ditch and Salmon Creek, and in the south wetlands area.

5.1.1 Horizontal Groundwater Gradients

Horizontal gradient estimates were calculated for four subareas at the RMC site. Estimates range from approximately 0.003 ft/ft for subareas located north of the RMC facility, south of South Ditch, and beneath the RMC plant to 0.02 ft/ft for the subarea east of the RMC facility. Corresponding shallow groundwater flow directions were predominantly toward the northwest, although localized variations occurred near the Sandy River, where groundwater flows toward the east, and also near the South Ditch, where groundwater flows toward the west.

On the basis of available shallow groundwater elevation data for site monitoring wells (presented in water level elevation contour maps Figure 5-1 and Figure 5-2), the general horizontal groundwater flow direction in the shallow zone is north and northwest toward the Columbia River. Contour maps also show that shallow groundwater flow directions and gradients vary in response to the influence of smaller drainage systems such as the Sandy River east of the site, Salmon Creek to the west, and other nearby surface water bodies (Company Lake, East Lake, and the South Ditch).

Estimates of shallow groundwater gradients from the contour maps presented in Figures 5-1 and 5-2 have been made for four subareas at the RMC site:

- North of the RMC facility (MW06, MW08, MW09, and to a lesser extent MW20)
- East of the RMC facility (MW05, MW10, and MW11)
- South of the South Ditch (MW03, MW17-16, and MW26)
- Beneath the RMC plant (MW01, MW04, and MW07)

Most of the flow direction and gradient estimates described below are based on wells that are separated by hundreds of feet and, therefore, they should be viewed as generalized. Because of observed heterogeneity of the shallow portion of the aquifer system, actual flow directions and gradients are likely to vary between locations that are separated by more than 100 feet.

5.1.1.1 North of the RMC Facility

Groundwater gradient estimates in areas north of the facility are based on water levels measured at MW06, MW08, MW09, and MW20. Groundwater gradients estimated for February 1995 and October 1995 are 0.002 and 0.003 ft/ft, respectively. The estimated February flow direction is generally toward the north-northeast, because the groundwater elevation at MW08 appears to be affected by the relatively high Columbia River stage, and is slightly higher than MW09. The estimated October 1995 groundwater flow direction is generally toward the north-northwest (see CH2M HILL, 1995e).

5.1.1.2 East of the RMC Facility

Groundwater gradient estimates in the area east of the facility are based on water levels measured at MW05, MW10, and MW11. Groundwater gradient estimates for February 1995 and October 1995 are 0.02 and 0.01 ft/ft, respectively. As previously discussed, a groundwater mound or ridge appears south of the dike during the wet season in response to concentrated precipitation infiltration and low-permeability soil conditions in this area. The mound is not evident under dry season conditions (Figure 5-2). The groundwater flow directions for both periods appear to be consistently to the northeast, toward the Sandy River.

5.1.1.3 South of the South Ditch

The groundwater gradient estimate for the area south of the South Ditch is based on water levels measured at MW03, MW17-16, and MW26. The groundwater gradient estimated for October 1995 was 0.003 ft/ft, and the general horizontal groundwater flow direction in the shallow zone was from east to west toward the south wetlands area. A gradient estimate was not calculated for February 1995 because monitoring wells MW17-16 and MW26 were not installed until July 1995. Groundwater measurements will continue to be monitored over the 1995-1996 monitoring season to determine whether an east-to-west groundwater flow direction trend persists in this area.

5.1.1.4 Beneath the RMC Plant

The groundwater gradient estimate for the area beneath the main plant buildings is based on water levels measured at MW01, MW04, and MW07. The groundwater gradient estimate for October 1995 is 0.002 ft/ft, and the general horizontal groundwater flow direction in the shallow zone beneath the facility appears to be toward the northwest. The groundwater contour map for October 1995 presents the groundwater table as a broad flat area beneath the RMC facility, although a depression may exist in the vicinity of the bakehouse. A gradient was not estimated for February 1995 because the October 1995 data provide better resolution because of the additional monitoring wells installed in July 1995.

5.1.2 Vertical Groundwater Gradients

Vertical hydraulic gradient estimates were calculated for five well pairs (MW02, MW17, MW18, MW21, and MW25) at the RMC site. Average vertical hydraulic gradient estimates ranged from 0.004 ft/ft upward to 0.67 ft/ft downward.

On the basis of shallow monitoring well and deep production well groundwater level data and available aquifer test data, the vertical hydraulic gradient in the plant vicinity is, in general, vertically downward. Additional groundwater level monitoring will be conducted during winter months to evaluate seasonal variability in the magnitude and direction of the vertical gradients in the shallow portion of the aquifer at the RMC site. Vertical gradients for groundwater data from July 1995 through November 1995 are presented in Table 5-2 for well pairs located at the RMC site. In general, average vertical hydraulic gradients at the site are downward, ranging from 0.27 ft/ft at the MW18 well pair to 0.67 ft/ft at the MW02 well pair. At MW17, the vertical gradient fluctuates very slightly around zero, indicating that there is little vertical gradient at that well pair. However, an average upward vertical gradient of 0.004 ft/ft was calculated based on the majority of the vertical gradient calculation results being in a slightly upward direction. On the basis of the 5-month period in which groundwater data have been collected at well pairs, vertical hydraulic gradients appear to vary with geographical location across the site as follows:

- **South of South Ditch.** Vertical hydraulic gradients for well pair MW17, located on the eastern boundary of the south wetlands, fluctuate slightly around zero, indicating that no significant vertical gradient exists in the upper 30 feet of the aquifer. The MW18 well pair, located on the western boundary of the south wetlands, shows a downward vertical gradient averaging about 0.27 ft/ft.

Table 5-2
Vertical Groundwater Gradient Estimates
Reynolds Metals Company
Troutdale, Oregon

Date	Well ID Groundwater Elevation (feet)		MW02 Well Pair Elevation Difference (feet)	MW02 Well Pair Vertical Gradient (foot/foot)	Well ID Groundwater Elevation (feet)		MW17 Well Pair Elevation Difference (feet)	MW17 Well Pair Vertical Gradient (foot/foot)	Well ID Groundwater Elevation (feet)		MW18 Well Pair Elevation Difference (feet)	MW18 Well Pair Vertical Gradient (foot/foot)	Well ID Groundwater Elevation (feet)		MW21 Well Pair Elevation Difference (feet)	MW21 Well Pair Vertical Gradient (foot/foot)	Well ID Groundwater Elevation (feet)		MW25 Well Pair Elevation Difference (feet)	MW25 Well Pair Vertical Gradient (foot/foot)
	MW02-12	MW02-24			MW17-16	MW17-28			MW18-16	MW18-31			MW21-12	MW21-25			MW25-24	MW25-35		
Vertical Separation *(a)*	9.20				12.00				15.50				13.40				14.60			
7/27/95	18.29	12.75	5.54	0.60	13.88	13.93	-0.05	0	13.53	10.31	3.22	0.21					16.46	10.48	5.98	0.41
7/31/95	18.22	12.60	5.62	0.61	13.72	13.69	0.03	0	13.43	10.19	3.24	0.21					16.51	10.34	6.17	0.42
8/1/95	18.17	12.63	5.54	0.60	13.23	13.63	-0.40	-0.03	13.39	10.20	3.19	0.21					16.45	10.31	6.14	0.42
8/3/95	18.10	12.30	5.80	0.63	13.46	13.45	0.01	0	13.32	9.87	3.45	0.22					16.34	10.01	6.33	0.43
8/7/95	17.95	11.86	6.09	0.66	13.29	13.26	0.03	0	13.25	9.43	3.82	0.25					16.07	9.68	6.39	0.44
8/24/95	17.44	11.08	6.36	0.69	12.74	12.70	0.04	0	12.90	8.89	4.01	0.26					14.77	9.04	5.73	0.39
9/7/95	16.87	10.56	6.31	0.69	12.44	12.52	-0.08	-0.01	12.72	8.44	4.28	0.28	15.44	7.19	8.25	0.62	13.82	8.64	5.18	0.35
10/5/95	16.79	10.27	6.52	0.71	12.42	12.44	-0.02	0	13.19	8.70	4.49	0.29	15.35	6.70	8.65	0.65	11.58	8.77	2.81	0.19
10/16/95	16.58	10.35	6.23	0.68	12.99	12.99	0.00	0	13.56	8.71	4.85	0.31	16.09	7.01	9.08	0.68	14.22	8.87	5.35	0.37
10/17/95	16.59	10.35	6.24	0.68	13.07	13.12	-0.05	0	13.34	8.55	4.79	0.31	16.13	7.86	8.27	0.62	15.12	8.80	6.32	0.43
10/19/95	16.61	10.70	5.91	0.64	13.24	13.24	0.00	0	13.85	9.09	4.76	0.31	16.22	7.50	8.72	0.65				
10/20/95	16.78	10.67	6.11	0.66	13.26	13.29	-0.03	0	13.90	9.11	4.79	0.31	16.27	7.52	8.75	0.65	15.79	9.26	6.53	0.45
10/21/95	16.87	10.79	6.08	0.66	13.30	13.38	-0.08	-0.01	13.93	9.43	4.50	0.29	16.23	7.53	8.70	0.65	15.83	9.46	6.37	0.44
11/3/95	18.43	11.03	7.40	0.80	13.63	13.63	0.00	0	14.47	9.31	5.16	0.33	16.48	7.70	8.78	0.66	16.47	9.29	7.18	0.49
Minimum				0.60				0				0.21				0.62				0.19
Maximum				0.80				-0.03				0.33				0.68				0.49
Average				0.67				-0.004				0.27				0.65				0.40

Notes:

Elevations are referenced to NGVD 1929.

(a) Vertical separation is the vertical distance (feet) between the midpoints of the screened intervals for the wells.
(b) Vertical gradient (feet/feet) is calculated as the change in groundwater elevation/T.
(c) Positive value indicates downward vertical gradient; negative value indicates an upward vertical gradient.

- **Scrap Yard Area.** The MW02 well pair has the highest, vertically downward, hydraulic gradient estimate (of the five well pairs measured), averaging 0.67 ft/ft. The MW25 well pair, located approximately 90 feet southwest of the MW02 well pair, averages 0.40 ft/ft in a vertically downward direction.

- **North Landfill Area.** Well pair MW21 has an average vertical hydraulic gradient estimate of approximately 0.65 ft/ft in a vertically downward direction.

Because information collected during drilling in July and August 1995 indicated that it is uncertain how representative the water level elevations at MW02-24 (installed in June 1994) are, MW02 was deepened and reconstructed in January 1996. Therefore, vertical gradient estimates derived at the MW02 well pair should be viewed as preliminary, and they may be revised as additional data are collected.

5.2 Hydraulic Properties

A single-well aquifer test, a multiple-well aquifer test, and slug testing at 20 monitoring well locations were conducted as part of the aquifer testing investigation at the RMC Troutdale facility. Individual well aquifer test and slug test methodologies are described in *Memorandum WP No. 2* (CH2M HILL, April 25, 1995). The multiple-well aquifer test is described in *Memorandum WP No. 12* (CH2M HILL, October 19, 1995). The aquifer tests can be summarized as follows:

- Eight shallow groundwater monitoring wells were slug tested (with a pneumatic packer assembly) in August 1995, and an additional 12 wells were slug tested (using either the slug-out recovery method or the pneumatic packer assembly method) in October 1995.

- A single-well aquifer test was conducted on June 29, 1995, at the Fairview Farms #4 well.

- A multiple-pumping well aquifer test was conducted on October 23–25, 1995, using four onsite groundwater production wells.

Two additional single-well aquifer tests will be completed at the facility during 1996. In addition, water levels were monitored in RMC wells during multiple-well pumping at the City of Portland's Columbia South Shore municipal wellfield in December 1995. These data will be analyzed and presented in a later report.

5.2.1 Slug Testing

The slug test results, presented in Table 5-3, indicate that hydraulic conductivity estimates for the shallowest portion of the aquifer range from 0.01 ft/day (4.2×10^{-6} cm/sec) at MW15 up to 104 ft/day (3.5×10^{-2} cm/sec) at MW09. The wide range of observed hydraulic

Table 5-3
Slug Test Data Summary
Reynolds Metals Company
Troutdale, Oregon

Well ID	Initial Depth to Water (feet bgs)	Groundwater Elevation (feet)	Top of Filter Pack Elevation (feet)	Bottom of Borehole Elevation (feet)	Screened Interval Elevation (feet)	Estimated Saturated Thickness [(a)] (feet)	Maximum Displacement (feet)	Hydraulic Conductivity (ft/day)	Hydraulic Conductivity (cm/sec)	Category [(b)]
MW01	10.25	18.00	18.20	5.20	6.2 to 16.2	12.80	1.41	20	7.1E-03	H
MW02-24	21.45	10.20	16.60	4.30	4.6 to 14.6	5.90	2.10	1.3	4.5E-04	I
MW03	4.30	25.39	20.40	9.40	10.4 to 18.4	11.00	5.74	1.7	6.1E-04	I
MW04	15.80	11.11	17.30	4.30	5.3 to 15.3	6.80	1.14	0.06	2.3E-05	L
MW05	7.97	26.02	19.60	6.40	6.6 to 16.6	13.20	6.16	2.0	7.1E-04	I
MW06	10.50	16.31	12.60	-0.90	0.6 to 10.6	13.50	2.28	4.3	1.5E-03	I
MW07	14.45	13.93	16.70	3.70	4.7 to 14.7	10.20	1.43	4.5	1.6E-03	I
MW08	12.29	13.03	8.80	-5.20	-4.2 to 5.8	14.00	0.98*	49*	1.7E-02	H
MW09	16.03	13.24	9.00	-5.00	-3.0 to 7.0	14.00	3.32*	100*	3.5E-02	H
MW10	16.45	13.83	20.90	2.90	4.9 to 19.9	10.90	0.87	2.9	1.0E-03	I
MW11	6.97	24.64	23.50	10.50	12.5 to 22.5	13.00	1.62	0.20	7.1E-05	L
MW12	6.00	16.53	6.20	-2.80	-0.8 to 4.2	9.00	7.05	0.29	1.0E-04	L
MW15	11.46	11.29	9.40	-3.10	-2.8 to 7.3	12.50	2.20	0.01	4.2E-06	L
MW17-16	14.59	12.68	14.80	7.80	8.8 to 13.8	4.90	0.82	5.3	1.9E-03	I
MW17-28	14.45	12.85	2.80	-3.70	-3.2 to 1.8	6.50	5.22	1.4	5.0E-04	I
MW18-16	10.80	13.18	12.00	4.50	5.5 to 10.5	7.50	1.29	0.56	2.0E-04	L
MW18-31	15.13	8.82	-3.50	-10.50	-5.0 to -10.0	7.00	5.99	0.45	1.6E-04	L
MW21-12	8.71	15.83	16.4	10.4	10.9 to 15.9	5.43	1.2	30	1.1E-02	H
MW21-25	17.30	7.30	5.00	-3.00	3.0 to -2.0	8.00	2.17	9.50	3.4E-03	I
MW25-35	22.55	8.34	-0.60	-7.10	-1.6 to -6.6	7.70	6.06	0.04	1.3E-05	L

Notes:

(a) Thickness is based on the saturated portion of the filter pack. Vertical flow above and below the filter pack was ignored.

(b) Slug test results have been placed into three relative categories:

1. Low (L = less than 1ft/day)
2. Intermediate (I = 1ft/day to 10 ft/day)
3. High (H = greater than 10 ft/day)

* Two slug tests were conducted at this location. The results presented in this table are an average of both test results.

bgs = below ground surface

conductivities supports earlier observations indicating that the shallow aquifer is composed of sediments deposited in a complex, and highly heterogeneous, fluvial depositional environment.

Twenty of the 31 shallow groundwater monitoring wells installed at the RMC site between July 1994 and September 1995 were tested to estimate hydraulic conductivity in the shallow portion of the aquifer. Figure 5-6 shows the well locations and the posted corresponding hydraulic conductivity estimates. Slug test data analysis was conducted using the Bouwer and Rice (1976) and Bouwer (1989) method for determining the hydraulic conductivity of unconfined aquifers with completely or partially penetrating wells. Time-drawdown plots with best fit lines are presented in Appendix C-1.

Where possible, slug tests were conducted by displacing water within the well by pressurizing the well casing with nitrogen gas. The nitrogen-packer method was used for slug testing 2-inch-diameter wells when the depth to groundwater was identified to be above the top of the screened interval (Table 5-3). If the static water level was below the top of the screened interval in a well, the slug-out recovery method was used to test the selected well. The nitrogen-packer method includes the following general steps:

- A pressure-cap assembly was installed on the wellhead.
- Two pressure transducers were placed into the well, one above the water table to measure changes in air pressure in the well casing, and one below the water table to measure changes in the height of the water column.
- The air above the water column was pressurized, using compressed nitrogen to force water from within the casing into the formation through the screened interval, taking care not to allow nitrogen to enter the screened interval.
- After an equilibrium period, the casing seal was released, allowing the water level in the well to return to the static level. The pressure transducer below the water table measured the water level as it returned to the static level.

If water levels were below the top of the well screen and the nitrogen-packer method could not be used, the following slug-out procedure was used:

- A pressure transducer was installed and allowed to equilibrate.
- A standard, solid stainless steel slug was lowered into the well below the water column, displacing approximately 1 to 2 feet of water.
- After an equilibration period, the slug was removed as rapidly as possible.
- The data logger assembly measured water levels as the well recovered to the static condition.

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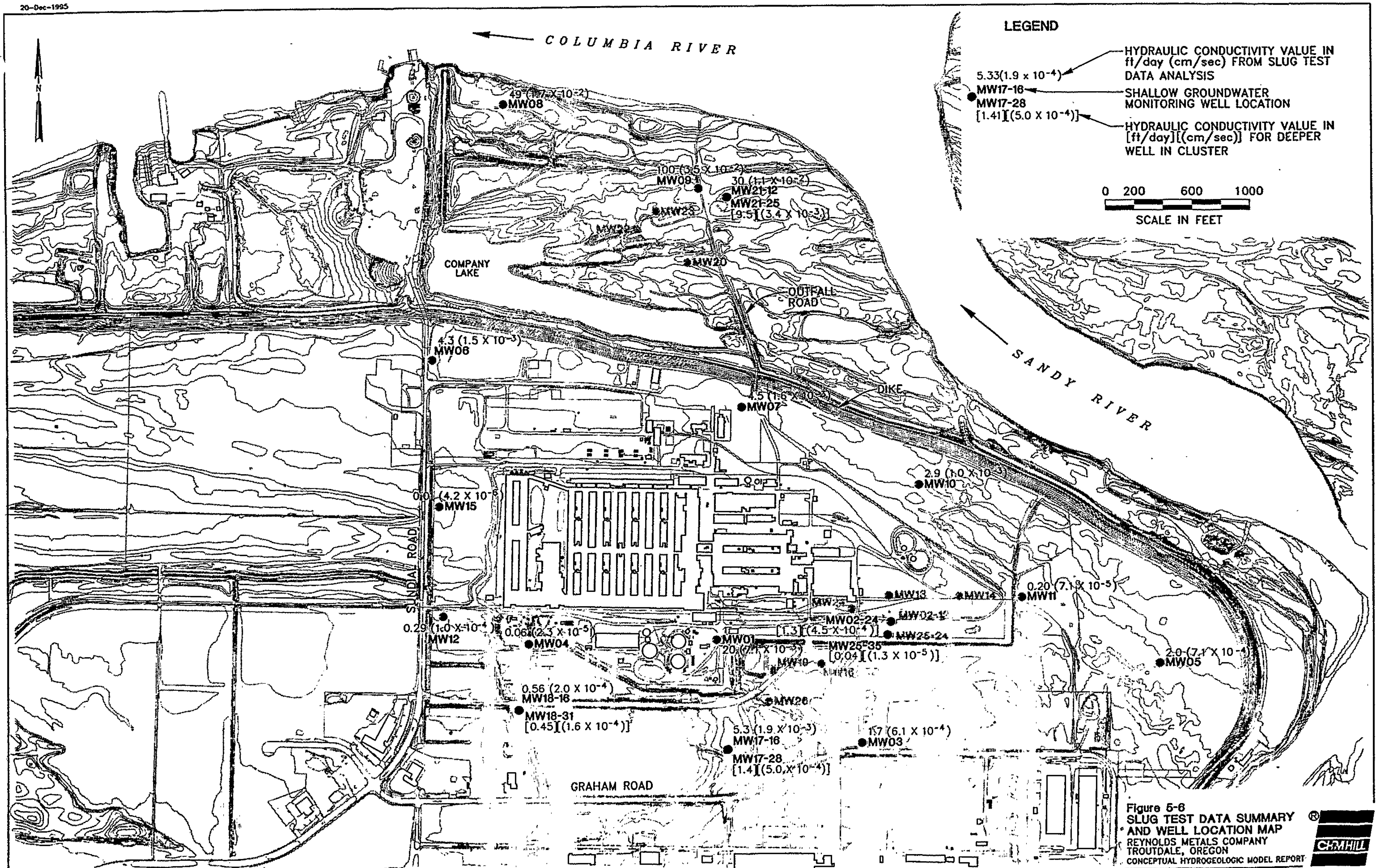

Figure 5-6
SLUG TEST DATA SUMMARY AND WELL LOCATION MAP
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
CONCEPTUAL HYDROGEOLOGIC MODEL REPORT
CH2MHILL

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The slug-out recovery method was also used for testing 4-inch-diameter wells (MW01, MW02-24, MW07, and MW10). Water containment and disposal were not necessary because no water was withdrawn from the wells during testing.

The slug-tested wells and the analytical results are shown in Figure 5-6. In general, the area north of the dike appears dominated by high-permeability sediments, with all four locations tested near or greater than 10 ft/day or 3.5×10^{-3} cm/sec [up to 104 ft/day (3.5×10^{-2} cm/sec) at MW09]. Low and intermediate hydraulic conductivity estimates are scattered throughout the areas south of the dike, supporting the observation that the shallow portion of the aquifer is composed of heterogeneous fluvial deposits and likely has bands or zones of varying permeability distributed throughout the site.

Some of the lowest permeabilities were observed:

- Near the south wetlands area, at MW18-16 (0.56 ft/day or 2.0×10^{-4} cm/sec), MW18-31 (0.45 ft/day or 1.6×10^{-4} cm/sec), and MW04 (0.06 ft/day or 2.3×10^{-5} cm/sec)
- Along Sundial Road near the western plant area boundary, at MW12 (0.29 ft/day or 1.0×10^{-4} cm/sec) and MW15 (0.01 ft/day or 4.2×10^{-6} cm/sec)
- The scrap yard at MW25-35 (0.04 ft/day or 1.3×10^{-5} cm/sec)
- The east potliner area at MW11 (0.20 ft/day or 7.1×10^{-5} cm/sec)

The highest hydraulic conductivity observed south of the dike is at MW01 (20 ft/day or 7.1×10^{-3} cm/sec). However, observations made at south landfill area wells MW16, MW19, and MW26 during drilling, development, and sampling activities indicate that these wells, if tested, may also exhibit relatively high hydraulic conductivities.

Three sets of paired wells were slug tested to determine whether vertical differences in hydraulic conductivity existed (Figure 5-6). Analysis of slug test data for well pairs MW17, MW18, and MW21 shows that hydraulic conductivity estimates are consistently lower in the deeper wells, regardless of well location at the site.

5.2.2 Single-Well Aquifer Test

A single-well aquifer test was conducted at the Fairview Farms #4 well on June 29, 1995. The aquifer test was conducted to provide an estimate of deep aquifer transmissivity and help evaluate responses to deep-aquifer pumping west of the facility. Fairview Farms #4 (FF04) is an irrigation well located approximately 1,300 feet west of Sundial Road, and approximately 1,100 feet south of the COE flood control dike (see Figure 5-7).

5.2.2.1 Groundwater Discharge

The aquifer test was conducted using the existing line-shaft turbine pump and booster pump. A special permit (contained in Appendix C-2) obtained from the Oregon Department of

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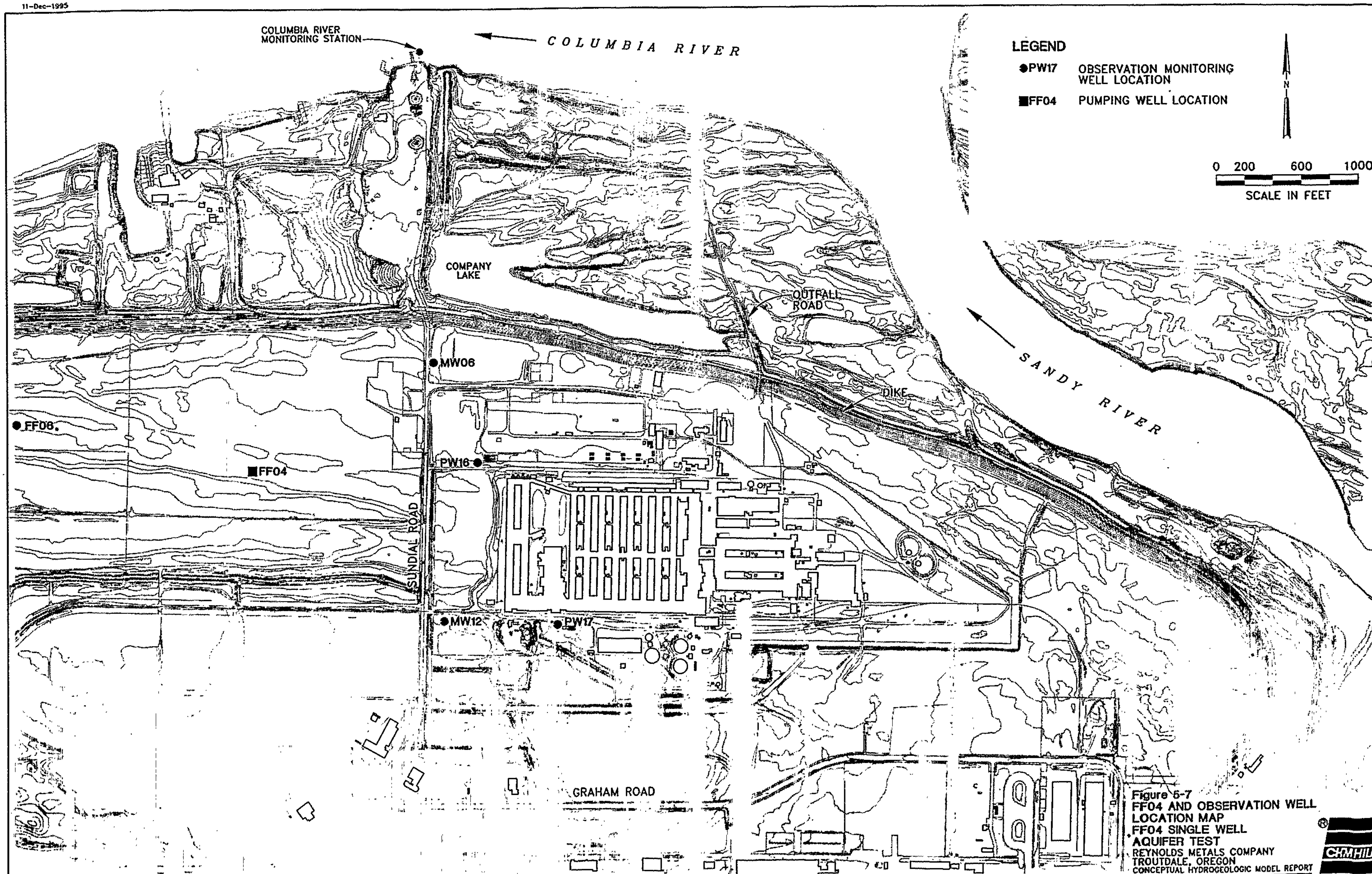

Figure 6-7
FF04 AND OBSERVATION WELL LOCATION MAP
FF04 SINGLE WELL AQUIFER TEST
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
CONCEPTUAL HYDROGEOLOGIC MODEL REPORT

9293SG26.DWG

Environmental Quality (DEQ) allows the groundwater produced during the test to be discharged into Salmon Creek. Salmon Creek is pumped into the Columbia River approximately ¾ mile west of FF04. Groundwater was discharged through 8-inch-diameter aluminum irrigation pipe into Salmon Creek approximately 700 feet south of the well.

The FF04 aquifer test began at 11:30 a.m. on June 29, 1995, using both the main shaft turbine pump and the auxiliary booster pump. The average discharge rate for the FF04 aquifer test was estimated by using an in-line totalizing flow meter installed in the pipe carrying the water to Salmon Creek. The average discharge during the pumping period was estimated to have been 990 gallons per minute.

The pumping portion of the aquifer test was scheduled to last approximately 17 hours, or until drawdown stabilized in the monitoring wells. At 7:05 p.m. on June 29, 7.6 hours (455 minutes) after the test began, an electrical malfunction caused the booster pump to fail, reducing the discharge rate by approximately one-half, from approximately 1,000 gpm to 500 gpm. The water level in FF04 quickly recovered between 3 and 4 feet, and then continued a slow rise. The main pump was shut off approximately 1 minute after the booster pump failed, and recovering water levels were monitored.

5.2.2.2 Monitoring Wells

In addition to water levels at FF04, water levels at three deep wells (FF06, PW16, and PW17), two shallow monitoring wells (MW06 and MW12), and the Columbia River stage elevation were monitored during the test. The observation wells monitored during the pumping test are shown in Figure 5-7. Water levels at FF04, PW16, PW17, and MW12 were measured manually with an electric water level indicator. Data logger and pressure transducer assemblies were installed at wells MW06 and FF06, and in the Columbia River.

5.2.2.3 Single-Well Aquifer Test Results

The FF04 single-well aquifer test was conducted to provide an estimate of deep aquifer transmissivity and help evaluate responses to deep aquifer pumping west of the facility. Field data sheets containing the water level measurements for the single-well aquifer test are included in Appendix C-2. The data were entered into the AQTESOLV (Geraghty & Miller, 1989) aquifer test analytical software package. AQTESOLV was used to curve match the observed time-drawdown in data using the Theis (1935), Cooper-Jacob (1946), Papadopulos-Cooper (1976), Hantush (1955; 1960), and Theis recovery (1935) solution methods. Use of these solution methods was based on their apparent applicability to aquifer conditions (unconsolidated confined to leaky confined aquifer) at the site. Plots of the analytical methods evaluated are included in Appendix C-2. Transmissivity estimates are shown in Table 5-4.

The screened portion of the aquifer system in the vicinity of Fairview Farms exhibits apparent transmissivities that range from 23,000 to 79,000 ft^2/day (2,137 to 7,339 m^2/day). The lower transmissivity estimate is derived from pumping well data; it may appear slightly lower than the actual transmissivity because of turbulent well losses in the production well.

Table 5-4
Aquifer Transmissivity Estimates from Time-Drawdown Data Collected During the FF04 Aquifer Test

Solution Method	Transmissivity (ft²/day)	Transmissivity (m²/day)	Storage Coefficient (dimensionless)	Remarks
Time-Drawdown and Recovery Data Collected in Well FF04				
Theis[1]	37,000	3,437	NA	Confined aquifer solution. Primarily matched to late data.
Cooper-Jacob[2]	39,000	3,623	NA	Confined aquifer solution. Primarily matched to late data.
Papadopulos-Cooper[3]	33,000	3,066	NA	Confined aquifer solution (including wellbore storage). Primarily matched to late data.
Hantush[4]	23,000	2,137	NA	Leaky confined aquifer solution. Considers storage in confining layer. Primarily matched to late data.
Theis Recovery[1]	30,000	2,787	NA	Confined aquifer solution. Primarily matched to late recovery data.
Time-Drawdown and Recovery Data Collected in Well FF06				
Theis[1]	48,000	4,459	0.002	Confined aquifer solution. Primarily matched to late data.
Cooper-Jacob[2]	79,000	7,339	0.001	Confined aquifer solution. Primarily matched to late data.
Papadopulos-Cooper[3]	55,000	5,110	0.002	Confined aquifer solution. Primarily matched to late data.
Hantush[4]	32,000	2,973	0.002	Leaky confined aquifer solution. Considers storage in confining layer. Primarily matched to late data.
Theis Recovery[1]	26,000	2,415	NA	Confined aquifer solution. Primarily matched to late recovery data.
Time-Drawdown and Recovery Data Collected in Well PW16				
Theis[1]	45,000	4,181	0.004	Confined aquifer solution. Primarily matched to late data.
Cooper-Jacob[2]	52,000	4,831	0.003	Confined aquifer solution. Primarily matched to late data.
Papadopulos-Cooper[3]	45,000	4,181	0.004	Confined aquifer solution. Primarily matched to late data.
Hantush[4]	45,000	4,181	0.004	Leaky confined aquifer solution. Considers storage in confining layer. Primarily matched to late data.
Theis Recovery[1]	40,000	3,716	NA	Confined aquifer solution. Primarily matched to late recovery data.

Table 5-4
Aquifer Transmissivity Estimates from Time-Drawdown Data Collected During the FF04 Aquifer Test

Solution Method	Transmissivity (ft²/day)	Transmissivity (m²/day)	Storage Coefficient (dimensionless)	Remarks
Time-Drawdown and Recovery Data Collected in Well PW17				
Theis[1]	49,000	4,552	0.004	Confined aquifer solution. Primarily matched to late data.
Cooper-Jacob[2]	43,000	3,995	0.003	Confined aquifer solution. Primarily matched to late data.
Papadopulos-Cooper[3]	49,000	4,552	0.004	Confined aquifer solution. Primarily matched to late data.
Hantush[4]	49,000	4,552	0.004	Leaky confined aquifer solution. Considers storage in confining layer. Primarily matched to late data.
Theis Recovery[1]	37,000	3,437	NA	Confined aquifer solution. Primarily matched to late recovery data.

[1] Theis, C.V., 1935.
[2] Cooper, H.H., and C.E. Jacob, 1946.
[3] Papadopulos, I.S., and H.H. Cooper, 1976.
[4] Hantush, M.S., and C.E. Jacob, 1955, and Hantush, M.S., 1960.
ft^2/day = square feet per day.
m^2/day = square meters per day.
NA = Not applicable.

The transmissivity estimates derived from observation well data agree closely, with an average of 46,000 ft^2/day (4,273 m^2/day). Aquifer storage coefficients based on the observation well data generally range from 0.002 to 0.004. This range of aquifer storage coefficients indicates that the system is responding like a leaky confined system. Storage coefficients less than 0.001 suggest a confined system; storage coefficients greater than 0.01 suggest an unconfined system.

The shallow aquifer response to pumping was monitored in only two locations, both east of the production well, near the western edge of the plant site. On the basis of the observed response to pumping at those locations, the degree of hydraulic connection between the shallow and deeper portions of the aquifer appears to exhibit significant variability.

Although groundwater elevations clearly responded to Columbia River stage fluctuations at most locations, no boundary condition resulting from surface water recharge to groundwater was observed in the test data. It is likely that a constant head boundary would have been observed if the test had been conducted at a greater discharge rate or for a greater length of time.

FF04. Transmissivity estimates range from 23,000 to 39,000 ft^2/day (2,137 to 3,623 m^2/day). The leaky confined aquifer solution (the likely actual condition in the Fairview Farms area), which also matches the best-fit curve to late-time data, gives a slightly lower transmissivity estimate [23,000 ft^2/day (2,137 m^2/day), shown in Table 5-4] than the estimates that assume the aquifer is perfectly confined [averaging 35,000 ft^2/day (3,252 m^2/day)]. The late-time data are likely to be more accurate than the data collected at the beginning of the test because the pumping rate is likely to have become relatively stable later in the test, and early data are more strongly affected by wellbore storage. None of the analytical methods using production well data provided reasonable storativity estimates.

FF06. A data logger and a pressure transducer assembly were used to measure water levels in FF06 during the aquifer test. FF06 is located approximately 1,400 feet (427 meters) west of FF04 (Figure 5-7). The pumping and recovery data are compared with smoothed and time-shifted Columbia River stage data in Figure 5-8. (The methodology is explained in greater detail in Section 5.2.3.)

Because the groundwater elevation data did not appear to show the twice-daily tidal fluctuations observed in the Columbia River raw data, the river stage data set was smoothed to remove the twice-daily fluctuations by applying a 12-hour moving average (Erskine, 1991; Serfes, 1991). The river stage data were then shifted forward along the time axis to bring the June 29 troughs observed in both data sets into alignment, indicating that there is an approximate 5-hour lag time during this time of year between a river stage fluctuation and the corresponding FF06 groundwater elevation fluctuation. Using a river efficiency[1] of 73 percent developed in Section 5.2.3 (using a more extensive data set), the predicted FF06 water level elevation (assuming no response to pumping at FF04) is also depicted in Figure 5-8.

[1] Ratio of groundwater elevation response to river stage fluctuation (Walton, 1970).

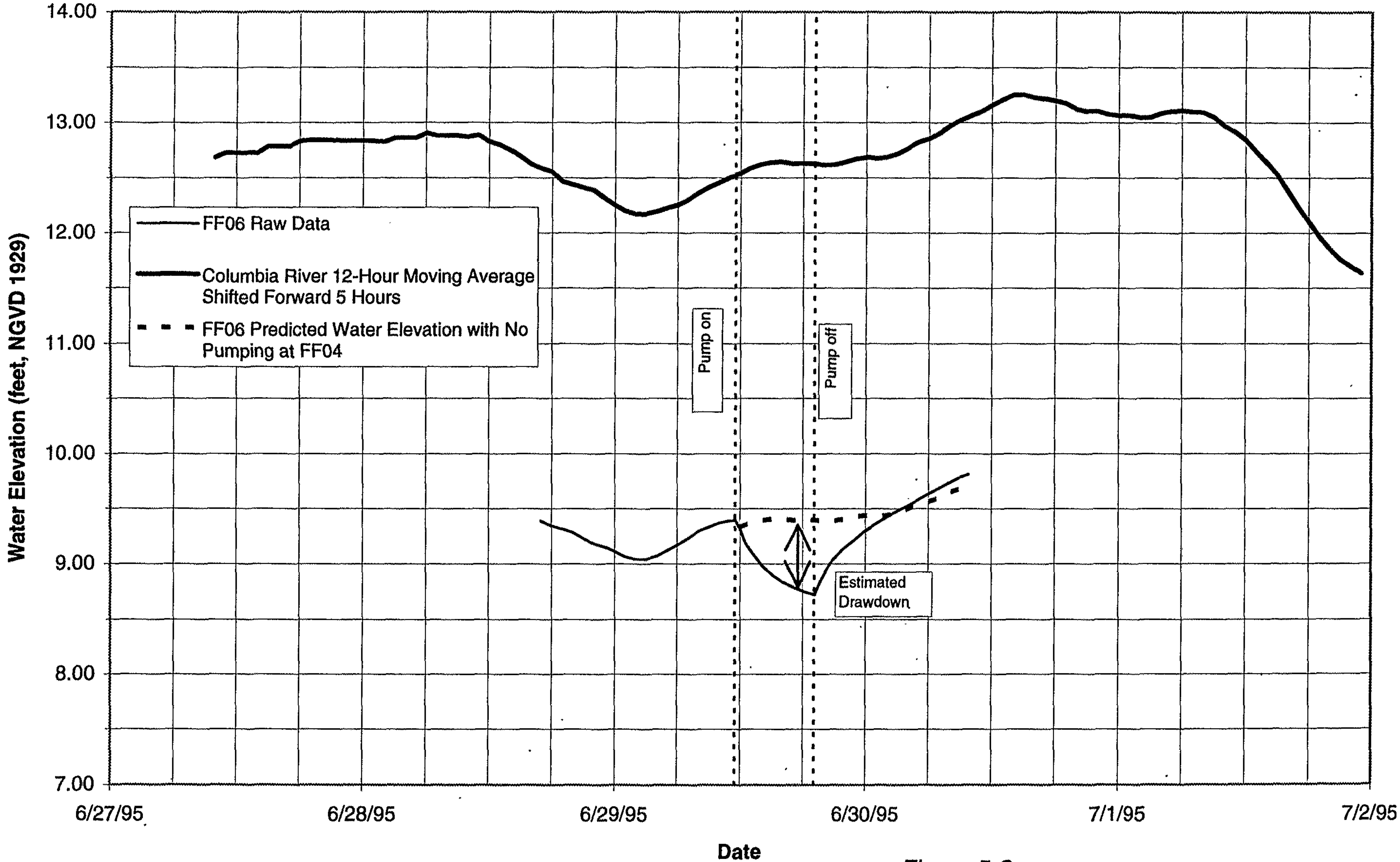

Figure 5-8
FF06 Estimated Drawdown
Reynolds Metals Company
Troutdale, Oregon

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Erskine (1991) estimated a tidal efficiency using the ratio of the standard deviation of the tidal data and the monitoring water level data. This method is preferred to using the ratio of individual peaks because it reduces the effect of individual reading errors, but it is strictly applicable only for identically formed signals symmetrical about their mean with continuous reading. The fluctuations observed in the Columbia River and FF06 water level data are not symmetrical about their mean because longer-term trends in water levels were present during the period of monitoring.

The FF06 groundwater elevation data were normalized to the pre-pumping water level and subtracted from the predicted water level to produce a time-drawdown data set that was analyzed by a method similar to that used for the FF04 pumping well data described above. The tabulated data and plots of the analytical methods evaluated are presented in Appendix C-2. The estimated transmissivity values for the FF06 observation well time-drawdown data are presented in Table 5-4.

Transmissivity estimates for the aquifer between FF04 and FF06 range from 26,000 to 79,000 ft^2/day (2,415 to 7,339 m^2/day). The estimated transmissivity using the leaky confined aquifer solution (the likely actual condition in the Fairview Farms area), which had been used for the FF04 analysis, also provides a slightly lower transmissivity estimate [32,000 ft^2/day (2,973 m^2/day), shown in Table 5-4] than the estimates that assume the aquifer is perfectly confined [averaging 52,000 ft^2/day (4,831m^2/day)]. Therefore, the actual aquifer transmissivity in the vicinity of the FF06 well is likely slightly lower than the 52,000 ft^2/day (4,831 m^2/day) late-time data average and closer to the 32,000 ft^2/day (2,973 m^2/day) value. These data may suggest a slight aquifer transmissivity increase between FF04 and FF06. However, the slight increase could be because drawdown in observation wells is not affected by turbulent well losses, which could result in more accurate transmissivity estimates. The average storage coefficient derived is 0.0018.

PW16. Manual water level measurements were collected at PW16 during the aquifer test. PW16 is located approximately 1,600 feet east of FF04 (Figure 5-7). The pumping and recovery data are compared with Columbia River stage data in Figure 5-9. Because the manual measurements do not provide enough resolution to correct the observed water level elevation measurements for river stage fluctuations, the PW16 groundwater elevation data were normalized to the pre-pumping water levels to produce a time-drawdown data set that was analyzed by a method similar to the one used for the FF06 observation well data described above. The tabulated data and plots of the analytical methods evaluated are presented in Appendix C-2. The estimated transmissivity values for the PW16 observation well time-drawdown data are presented in Table 5-4.

Transmissivity estimates for the aquifer between FF04 and PW16 range from 40,000 to 52,000 ft^2 /day (3,716 to 4,831 m^2/day). The range of transmissivity estimates derived from the perfectly confined and leaky confined solution methods at this location do not vary significantly. The estimated transmissivity using the leaky confined aquifer solution (the likely actual condition) provides a transmissivity estimate of 45,000 ft^2/day (4,181 m^2/day), compared with the 46,000 ft^2/day (4,273 m^2/day) average derived from estimates that assume the aquifer is perfectly confined. These data indicate that the aquifer may be more

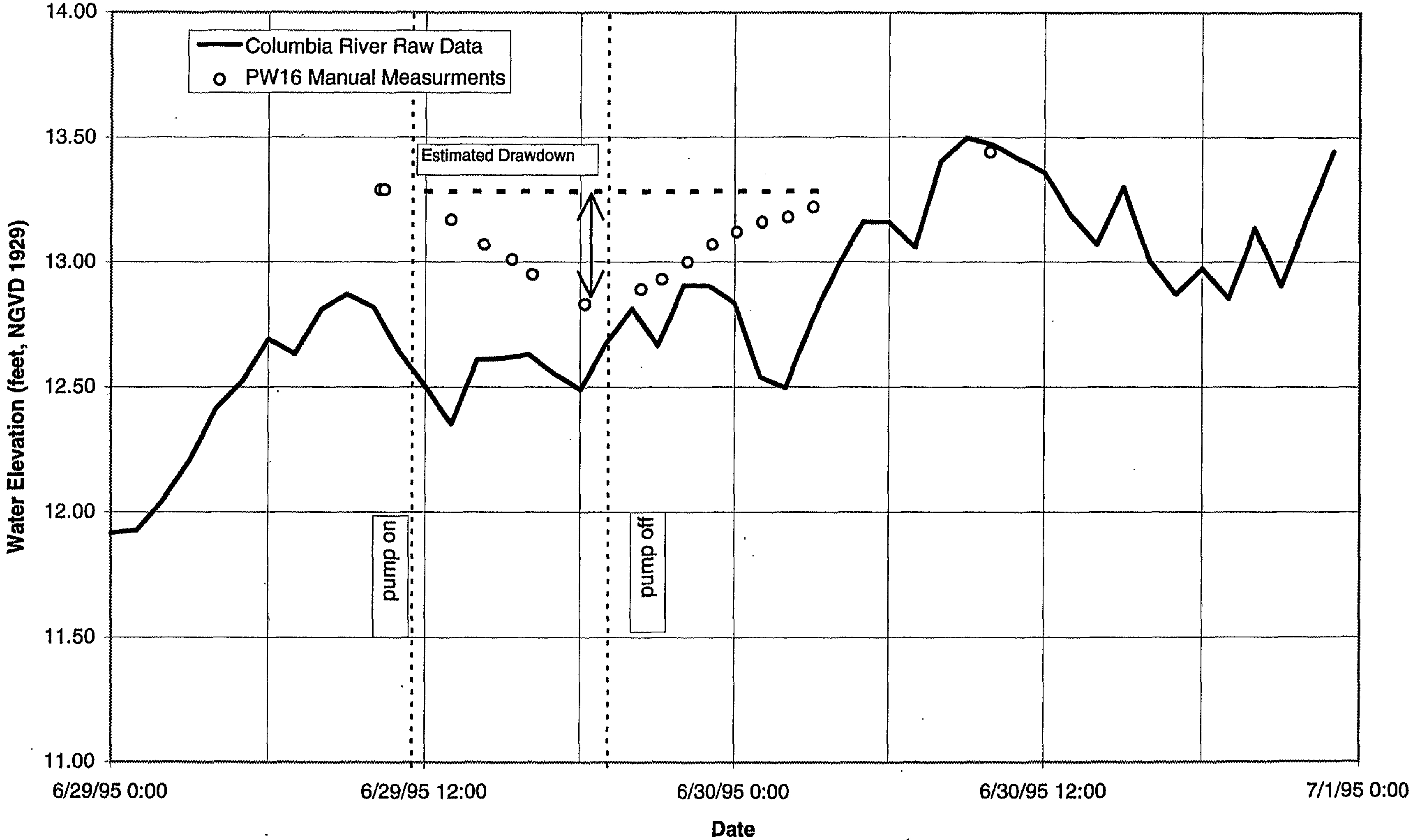

Figure 5-9
PW16 Estimated Drawdown
Reynolds Metals Company
Troutdale, Oregon

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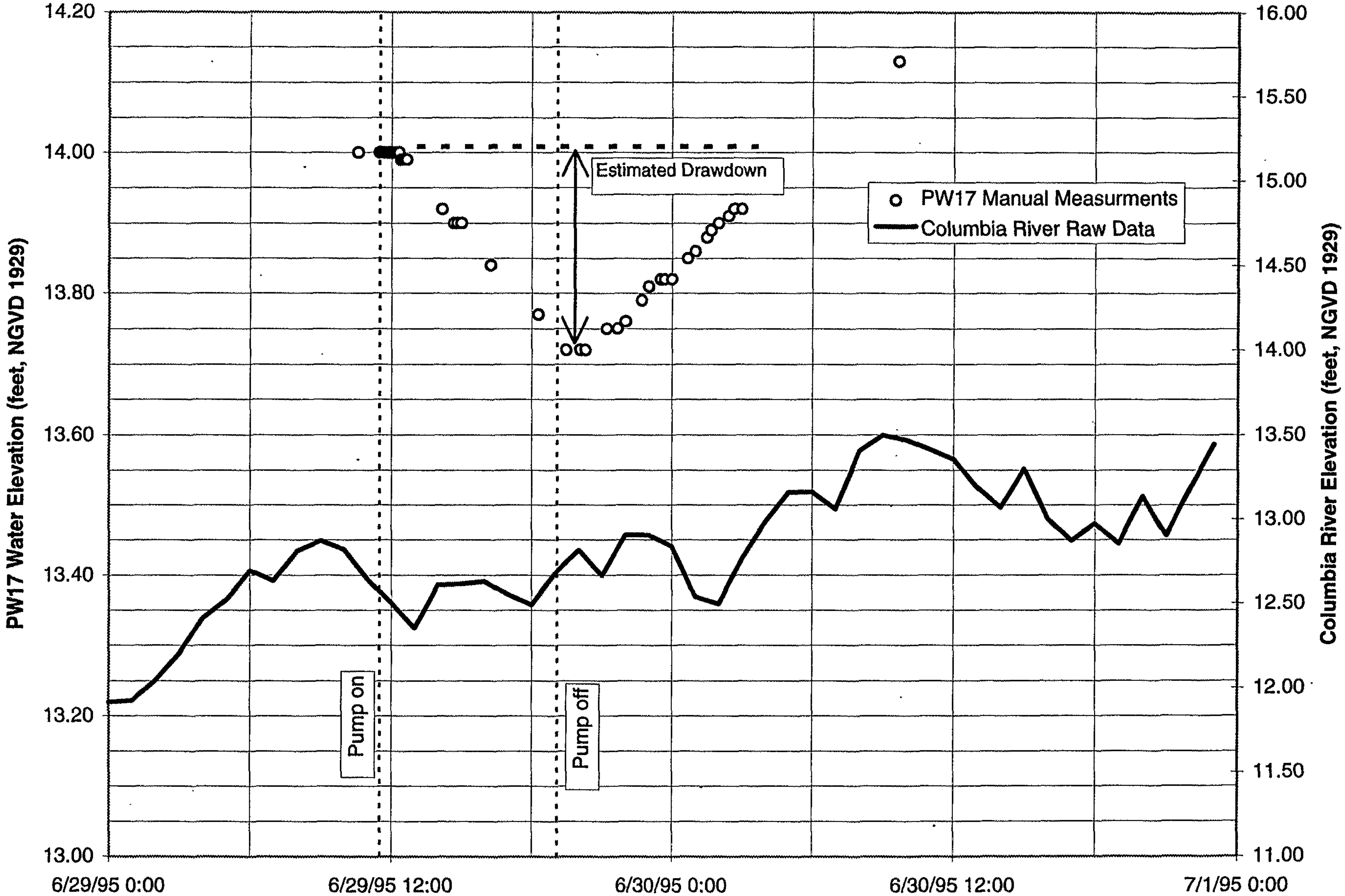
effectively confined (due to less leakage from the confining layer) east of FF04. The average storage coefficient is 0.0038.

PW17. Manual water level measurements were collected at PW17 during the aquifer test, approximately 2,400 feet (732 meters) southeast of FF04. The pumping and recovery data are compared with raw Columbia River stage data in Figure 5-10. Because the manual measurements do not provide enough resolution to correct the observed water level elevation measurements for river stage fluctuations, the PW17 groundwater elevation data were normalized to the pre-pumping water levels to produce a time-drawdown data set that was analyzed by a method similar to the one used for the PW16 observation well data described above. The tabulated data and plots of the analytical methods evaluated are presented in Appendix C-2. The estimated transmissivity values for the PW17 observation well time-drawdown data are presented in Table 5-4.

Transmissivity estimates for the aquifer between FF04 and PW17 range from 37,000 to 49,000 ft^2/day (3,437 to 4,552 m^2/day), similar to the transmissivity estimates derived from the PW16 time-drawdown data. The range of transmissivity estimates derived from the perfectly confined and leaky confined solution methods at PW17 also do not vary significantly. The estimated transmissivity using the leaky confined aquifer solution (the likely actual condition) provides a transmissivity estimate of 49,000 ft^2/day (4,552 m^2/day), compared with the 45,000 ft^2/day (4,181 m^2/day) average derived from estimates that assume the aquifer is perfectly confined. These data support the observation that the aquifer may become more effectively confined east of FF04. The average storage coefficient is 0.0038.

MW06. During the aquifer test, a data logger and a pressure transducer assembly were used to measure water levels at shallow monitoring well MW06, located approximately 1,500 feet (457 meters) east of FF04 (Figure 5-7). The pumping and recovery data are compared with smoothed and shifted Columbia River stage data in Figure 5-11. Because the MW06 groundwater elevation data did not show the twice-daily tidal fluctuations observed in the Columbia River (see Figure 5-11), the river stage data set was smoothed to remove the twice-daily fluctuations by applying a 12-hour moving average (Erskine, 1991; Serfes, 1991). (The methodology is explained in greater detail in Section 5.2.3.) The river stage data were then shifted forward 5 hours along the time axis to bring the observed peaks and troughs into alignment, indicating that there is an approximate 5-hour lag time during this time of year between a river stage fluctuation and the corresponding MW06 shallow groundwater elevation fluctuation. A river efficiency (Walton, 1970) estimate of 54 percent (see Figure 5-11), was used to develop the predicted water level elevation (assuming no response to pumping at FF04). The MW06 groundwater elevation data were then normalized to the pre-pumping water level and subtracted from the predicted water level to produce a time-drawdown data set.

The tabulated data and a semi-log plot of the pumping and recovery data are presented in Appendix C-2. A maximum drawdown of 0.34 ft was observed at MW06. The data were not used to estimate a transmissivity because the pumping well and observation well are screened in different zones. The 0.34 ft of drawdown observed at MW06 (screened 13.5 to



Date

Figure 5-10

PW17 Estimated Drawdown

Reynolds Metals Company

Troutdale, Oregon

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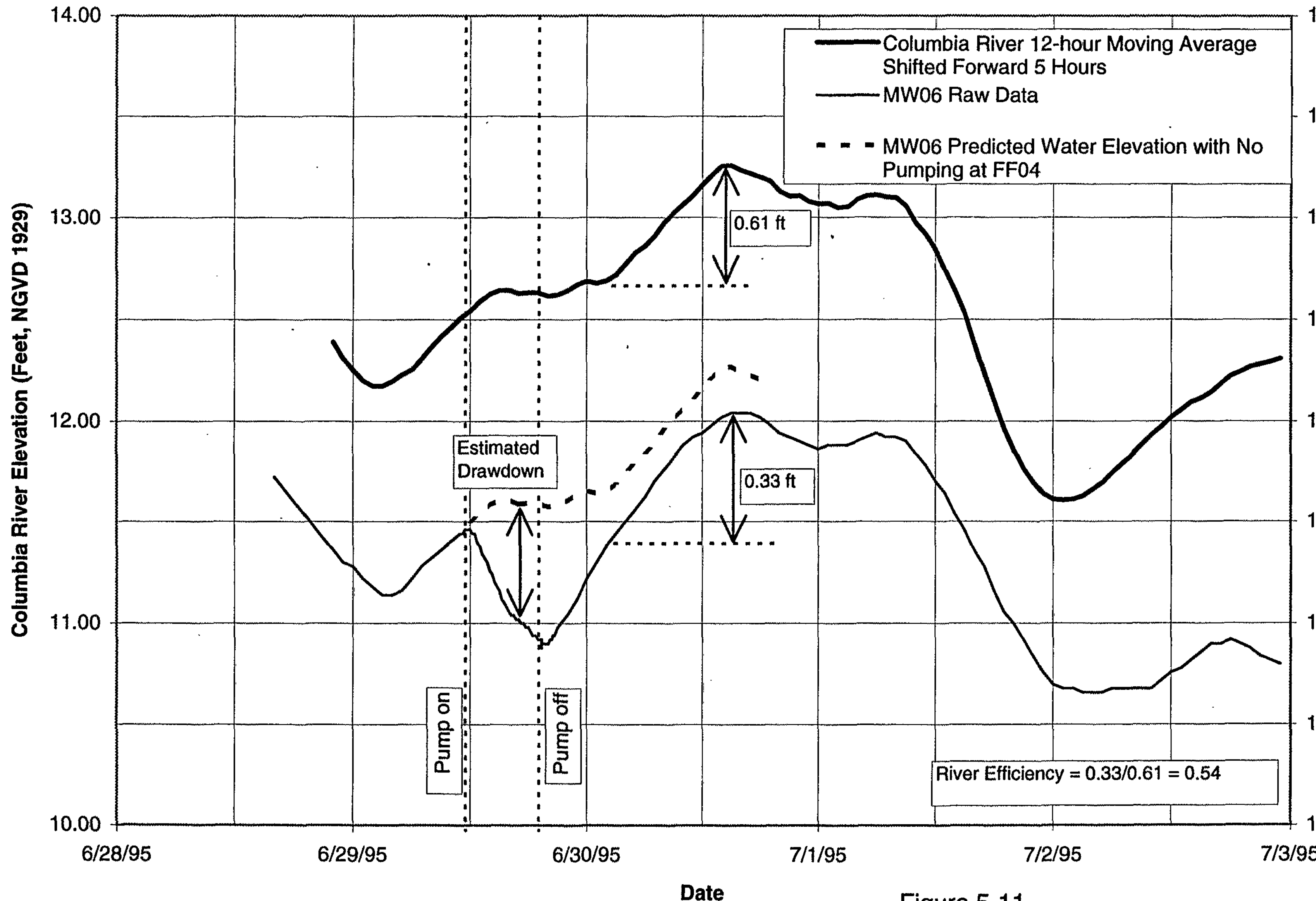

Figure 5-11
Estimated MW06 Drawdown
Reynolds Metals Company
Troutdale, Oregon

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23.5 ft bgs) is 26 percent less than the 0.46 ft of drawdown observed at PW16 (screened 151 to 192 ft bgs, and 256 to 269 ft bgs), a similar distance from FF04.

MW12. Manual water level measurements were collected at shallow monitoring well MW12 during the aquifer test, located approximately 1,500 feet (457 meters) southeast of FF04 (Figure 5-7). The MW12 pumping and recovery data are compared with raw Columbia River stage data in Figure 5-12. Because the MW12 groundwater elevation data do not appear to have responded to either the Columbia River or pumping at FF04, the data have not been further reduced and no additional analysis was conducted.

Because deep observation well PW17 responded similarly to PW16 and because MW06 (near PW16) exhibited response to pumping, the lack of response at MW12 may indicate that the degree of hydraulic connection between the shallow and deep portions of the aquifer is significantly decreased south of PW16.

5.2.3 Multiple-Well Aquifer Test

The aquifer test described below was used to simulate the aquifer response to the expected full-production-capacity, peak groundwater withdrawal condition at the RMC facility. The aquifer test was intended to help develop a better understanding of the flow system and the interaction between the shallow and deeper portions of the aquifer, and to provide data that will support planned predictive analysis. Four wells were pumped at a cumulative discharge rate expected to exceed the maximum long-term production demand. Because four wells were pumped simultaneously and screened interval elevations vary between production wells, the multiple-well test data were not used for a quantitative estimate of aquifer parameters. Single-well aquifer tests (FF04, presented in the previous subsection, and future planned tests) will be used to estimate aquifer parameters. Data gathered during this test are used to:

- Qualitatively identify areas of greater or lesser hydraulic connection between the deep and shallow portions of the aquifer. The magnitude or variability of the water level response in shallow groundwater monitoring wells to deep aquifer pumping will be used to help define the conceptual hydrogeologic model at the site and may identify uncertainties associated with the conceptual model that indicate the need for additional data collection efforts.

- Provide data to help assess the potential for hydraulic connection between the RMC site and aquifers west of the facility.

- Provide data to support future predictive analysis of groundwater flow and transport modeling of variable onsite and offsite pumping conditions.

As part of RMC's water supply system, 18 groundwater production wells were installed between 1942 and 1970. Of these 18 production wells, four (PW03, PW07, PW08, and PW10) are currently used on a regular basis for water production. The remaining wells have been decommissioned (PW15), abandoned (PW04, PW06, PW09, PW11, PW13, PW14, and

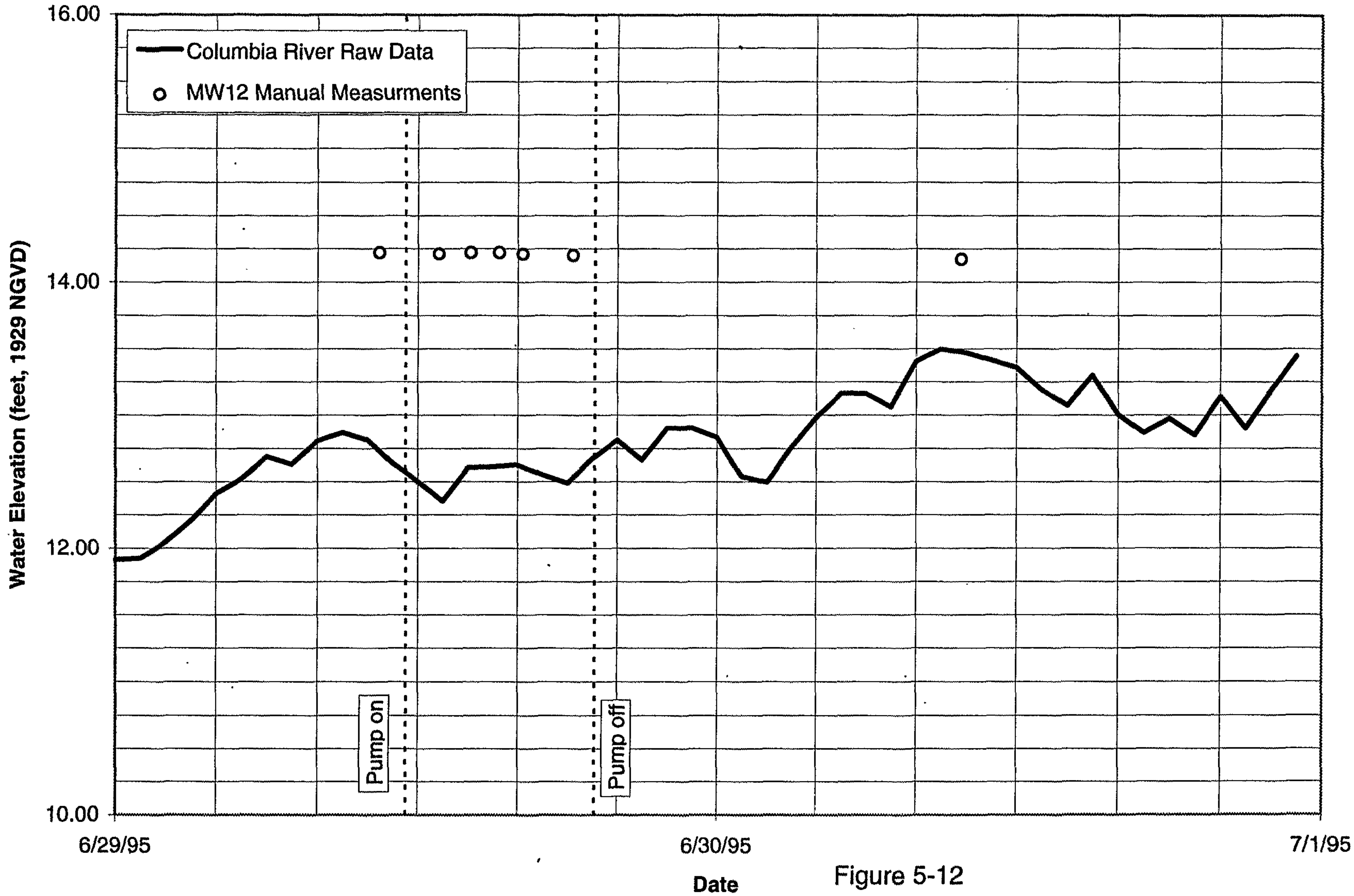

Figure 5-12
MW12 and Columbia River Hydrographs
Reynolds Metals Company
Troutdale, Oregon

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PW16), or are currently inactive (PW01, PW02, PW05, PW12, PW17, and PW18). Table 5-5 provides general well construction details and the current status for each production well. Table 5-5 also contains general construction details of two offsite irrigation wells (Fairview Farms #4 and #6) that were monitored during the aquifer pump test.

The facility currently uses an average of approximately 400 gpm, with brief peak demand periods at 600 gpm to support casthouse operations. This pumping has created groundwater levels at the facility that fluctuate with short-term changes in production but are relatively stable in the long term. The maximum amount of time that the facility can support casthouse operations without pumping groundwater is between 3 and 4 hours. Because existing conditions are relatively stable, and 4 hours without pumping is not likely to result in a static water level condition, the test was begun without a pre-test recovery (zero-pumping) period. It is likely that a short zero-pumping period prior to the test would result in dynamic water level responses that would create difficulty and uncertainty in the data analysis.

5.2.3.1 Groundwater Discharge

The aquifer test was conducted by pumping four regularly used production wells (PW03, PW07, PW08, and PW10). The aquifer test was conducted using existing RMC pumps, controls, and discharge piping. Because the RMC water supply system does not have the storage capacity to contain the volume of water produced during this aquifer test, excess water (not needed for cooling or process water) was discharged through RMC's supply system to the South Ditch. This water, along with other surface water runoff and treated process water collected in the South Ditch, was pumped from the South Ditch pumping station to Company Lake.

The aquifer test began at 8:00 a.m. on October 23, 1995, when the normal "on-demand" operation at production wells PW03, PW07, PW08, and PW10 was interrupted and the wells were placed on a "manual" (constant production) setting, raising the cumulative discharge rate from an average of about 400 gpm to an estimated 2,900 gpm. Discharge rate estimates (from RMC files) for the individual wells were provided by RMC and are listed in Table 5-6.

Table 5-5
Deep Zone Well General Construction Details
Reynolds Metals Company
Troutdale, Oregon

Well Inventory No.	Well Location (by 1/4-1/4 Section)	Original Well Owner	Date Completed	Original Well Use (a)	Total Well Depth (ft bgs) (b)	Well Yield (gpm) (c)	Static Water Level from Original Well Report (ft bgs)	Screened or Perforated Interval (ft bgs)	Water-Bearing
T1N R3E									
Section 22									
FF06	22adcc	Fairview Farms Inc. Well # 6	1950	I	200	1,200	17	119 - 200	Fine gray clay matrix; Well formerly used for irrigation. Owned by RMC.
Section 23									
FF04	23bcc	Fairview Farms Inc. Well # 4	1943	I	281	700	11	237 - 250	Sand and gravel; Well formerly used for irrigation. Owned by RMC.
Reynolds Metals Company (RMC) Production Wells									
PW01	23bdda	RMC Well # 01	1942	P	282	750	85	265 - 277	Loose gravel & conglomerate
PW02	23acca	RMC Well # 02	1942	P	268	400	78	251 - 263	Very loose gravel & sandy gravel
PW03	23acda	RMC Well # 03	1942	P	281	NA	72	253 - 264	Gravel & coarse gray sand
PW04	23adca	RMC Well # 04	1942	P	190	1300	53	170 - 180	Gravel & coarse sand.
PW05	23adcb	RMC Well # 05	1943	P	330	NA	60	160 - 180	Cemented gravel & loose sand
								182 - 187	Loose sand/gravel with clay
								248 - 253	Tight gravel
PW06	23adcb	RMC Well # 06	1952	P	279	NA	55	190 - 210	Coarse sand
								267 - 276	Loose sand with clay
PW07	23adcd	RMC Well # 07	1952	P	254		70	223 - 230	Blue/brown clay
								232 - 246	Loose gravel/sand
PW08	23adca	RMC Well # 08	1952	P	248		60	158 -174	Loose sand & gravel
								195 - 206	Loose sand & gravel
								210 - 218	Loose & cemented sand/gravel
								235 - 242	Sand & silt
PW09	23acdc	RMC Well # 09	1949	P	180		105	155 - 180	Gray sand
PW10	23acdc	RMC Well #10	1955	P	625	1,100	78	144 - 185	
								440 - 482	Sandy clay & gravel
								522 - 530	Sand & gravel
								538 - 558	Sand & gravel

Table 5-5
Deep Zone Well General Construction Details
Reynolds Metals Company
Troutdale, Oregon

Well Inventory No.	Well Location (by 1/4-1/4 Section)	Original Well Owner	Date Completed	Original Well Use (a)	Total Well Depth (ft bgs) (b)	Well Yield (gpm) (c)	Static Water Level from Original Well Report (ft bgs)	Screened or Perforated Interval (ft bgs)	Water-Bearing
PW11	23acdd	RMC Well #11	1955	P	592	1,500	45	150 - 163 417 - 434 502 - 533	Sand & gravel at both zones.
PW12	23dbab	RMC Well #12	1954	P	584	1,475	39	147 - 187 512 - 518 522 - 538 544 - 555 563 - 578	Coarse sand Loose sand & gravel at next 4 perforated zones.
PW13	23dbad	RMC Well # 13	1949	P	195	1,200	105	143 - 190	Coarse sand, some small gravel. Location approximate
PW14	23dbad	RMC Well # 14	1949	P	644		49	150 - 189	
PW15	23daba	RMC Well # 15	1953	P	275	1,350	41	255 - 273	Sand & gravel. Decommissioned February 1995.
PW16	23bdca	RMC Well # 16	1967	P	279	545	16	151 - 192 256 - 269	Sand with some gravel Sand, silt & gravel
PW17	23caad	RMC Well # 17	1969	P	310	1,090	20	170 - 207 221 -238 280 - 300	Sand & fine gravel Sand, some gravel Sand, some gravel
PW18	23dabc	RMC Well # 18	1970	P	300	1,090	15.75 *	148 - 189 229 - 260	Sand Sand & gravel

NOTES:

1. Well log information compiled from original Water Well Report forms collected from Oregon Water Resources Department, Salem, Oregon. Also literature review from McCarthy, 1990.
2. Refer to Figure__ for approximate well locations and Appendix __ for well logs.

(a) Original Well Use:
P = Production Wells
I = Irrigation

(b) ft bgs = feet below ground surface.

(c) Well yield reported in gallons per minute.
Yield value from pumping (air test, boiler test, etc.) test rate performed after well completion.

NA = Information not available.

* Static Water level for February 2, 1995.

Table 5-6
Estimated Production Well Discharge Rates
Reynolds Metals Company
Troutdale, Oregon

Production Well	Estimated Discharge Rate (gpm)
PW03	800
PW07	635
PW08	450
PW10	1,000
Total	2,885

As a condition of an existing NPDES permit, RMC monitors discharge from Company Lake to the Columbia River with a continuous recorder installed at a calibrated weir near the outfall. The discharge flow rate data collected at the weir from October 20 to 30, 1995, are presented in Figure 5-13. The average discharge rate prior to the aquifer test was approximately 1.25 mgd, or 870 gpm. The discharge rate at the Company Lake outfall did not appear to have reached equilibrium with the increased aquifer test pumping rate before the test was discontinued. However, if the discharge spike resulting from the precipitation event that occurred on October 25, 1995, at the end of the test is ignored, and the shape of the curve is estimated as if the test had continued long enough for the system to equilibrate, it appears that the increase in discharge rate would have leveled off at approximately 3.6 mgd, or 2,500 gpm, which reasonably agrees with the cumulative total estimate in Table 5-6. Slightly above-normal water system pressure caused by pumping these wells simultaneously may have resulted in a cumulative discharge rate slightly lower than the sum of the individual estimated flow rates.

Although the data do not represent an accurate measurement of the total groundwater withdrawn during the test, the cumulative discharge estimate provided in Table 5-6 and the estimated equilibrated Company Lake outfall rate provide the basis for a reasonable estimate of 2,800 to 2,900 gpm, resulting in a cumulative groundwater withdrawal of 9.8 to 10.2 million gallons during the pumping period. This rate exceeded the average production pumping rate of approximately 1,800 gpm that has been reported during full-production-capacity operations at the facility.

The water elevation of Company Lake increased 0.5 ft, from approximately 15.6 ft on October 23 at 8:00 a.m. to 16.1 ft on October 25 at 12:00 noon. This increase occurred before the rainfall event that began at approximately 12:00 noon on October 25. Assuming a lake area of 680,000 square feet (approximately 14 acres), this 0.5-ft increase in lake elevation indicates that the water storage in Company Lake increased by approximately 3.4 million gallons. Over the 52-hour period necessary for this 0.5-ft increase to occur, the average rate of storage increase was approximately 1,000 gpm during the course of the test.

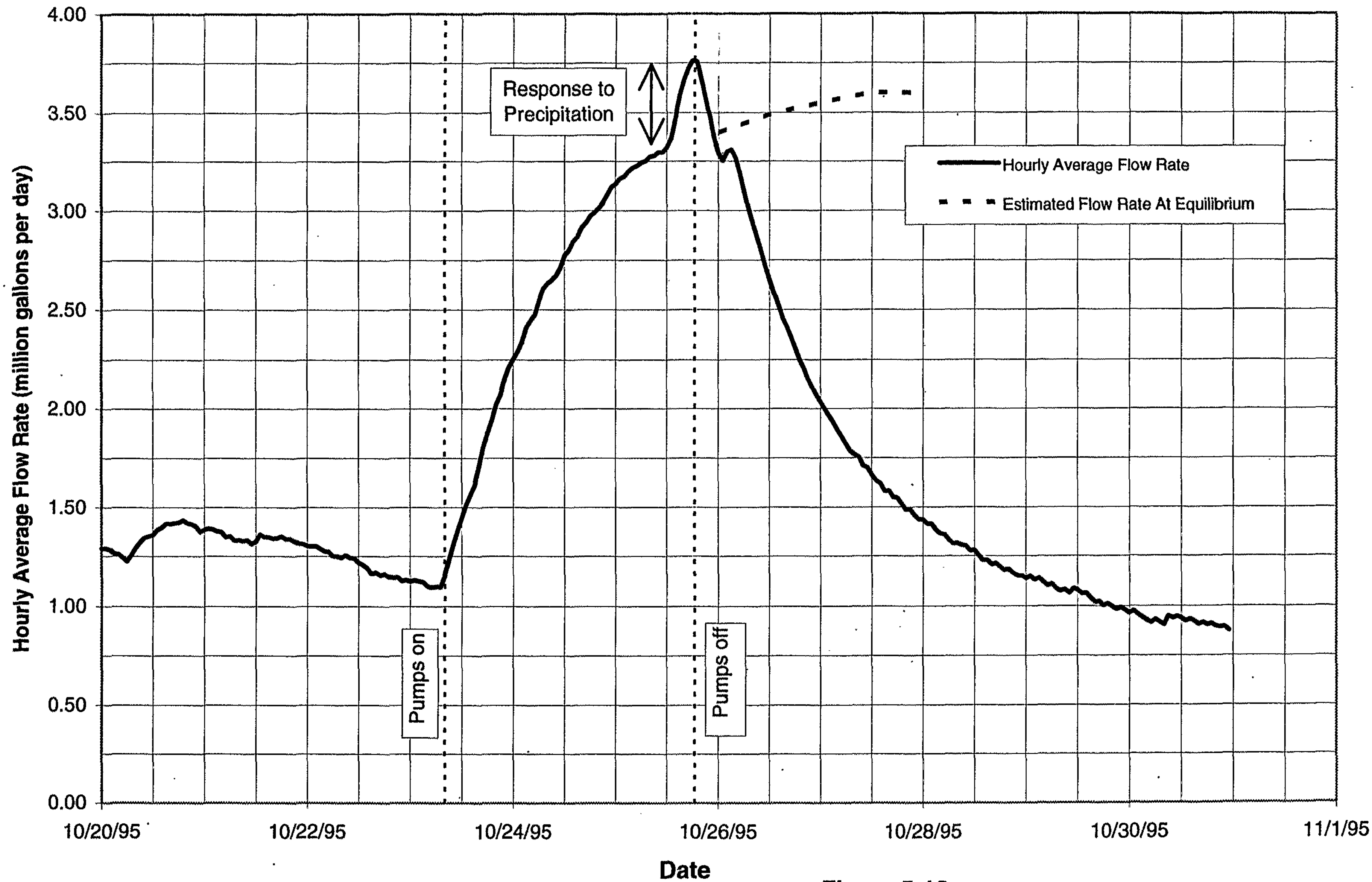

Figure 5-13
Company Lake Outfall Hourly Average Flow Rate
Reynolds Metals Company
Troutdale, Oregon

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In addition to the normal Company Lake outfall water quality monitoring that RMC conducted under the existing NPDES permit, CH2M HILL measured total suspended solids (TSS), dissolved oxygen (DO), temperature, pH, and electrical conductivity at the outfall monitoring station periodically during the duration of this test (field measurements were collected approximately hourly).

During the aquifer test, field measurements for temperature, electrical conductivity, and pH were collected at the pumping production wells approximately every 2 hours. Fluoride samples were collected near the beginning (within 1/2 hour of the start of the test) and end (approximately 58 hours later) of the aquifer test to evaluate the ability of short-term peak pumping to increase fluoride concentrations in deep groundwater. The water samples from the production wells were collected by opening spigots on the discharge pipe at each wellhead. Fluoride samples were collected into laboratory-prepared sample containers. One duplicate fluoride sample was collected for quality assurance/quality control.

The pumping phase of the test was discontinued in response to a precipitation event on October 25 at 6:30 p.m. after 58.5 hours of pumping. After a 24-hour period of light, sporadic rain beginning October 24, heavy precipitation began to fall on the 25th at approximately 12:00 noon. The daily total precipitation for this period measured at the Portland International Airport (approximately 10 miles west of the site) is plotted in Figure 5-14. Rainfall data are tabulated in Appendix C-3. The combined groundwater discharge and stormwater runoff rate into the South Ditch exceeded the pumping capacity of the two pumps at the South Ditch pumping station, resulting in a rapid water level increase in the South Ditch at approximately 5:00 p.m. The water approached a level that could cause water to overflow from the South Ditch into the south wetlands. CH2M HILL staff decided to stop the aquifer test as soon as the groundwater level monitoring system (data loggers and personnel) could be modified to allow collection of higher-frequency recovery water level data. At 6:30 p.m., the four pumps were stopped.

At approximately 6:00 p.m., a small volume (an estimated 10 to 15 gpm) of water began flowing from the South Ditch into the drainage that formerly connected the South Ditch to the south wetlands area. Because this connecting drainage slopes from the south wetlands toward the South Ditch, the water pooled in the north end of the ditch. The overflow was observed to cease within 15 to 20 minutes of discontinuing pumping. No water was observed to flow through the ditch into the south wetlands.

During the recovery period beginning at 6:30 p.m., RMC continued to pump groundwater to meet facility water demands. Groundwater withdrawals that occurred during the first 2 hours of recovery water level monitoring are listed below:

- PW07 was on from 7:08 to 7:26 p.m.
- PW07 and PW08 were on at 7:35 p.m. for 10 seconds
- PW07 was on from 8:00 to 8:18 p.m.

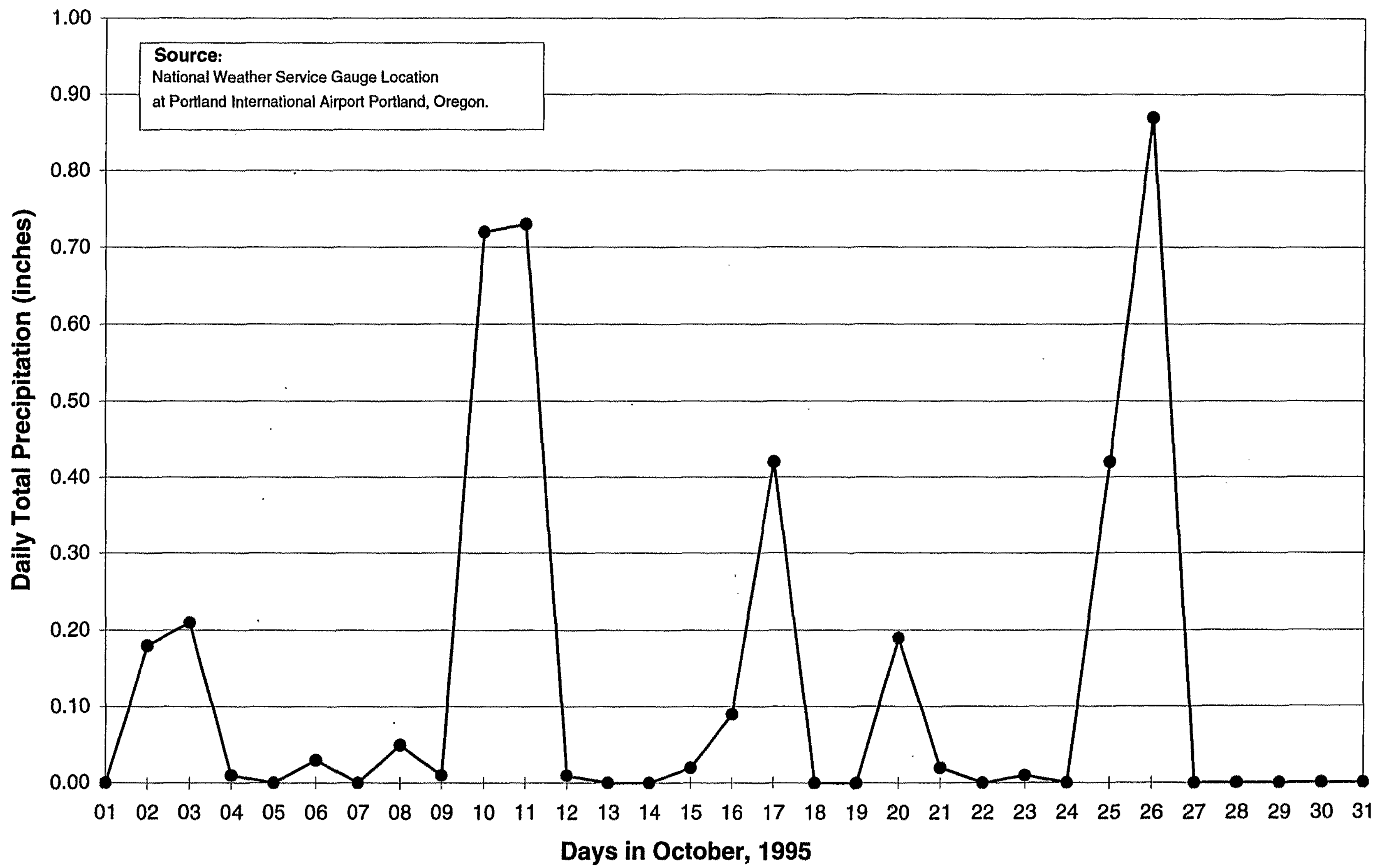

Figure 5-14
Daily Total Precipitation
Reynolds Metals Company
Troutdale, Oregon

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Therefore, non-pumping conditions lasted only the first 38 minutes of the recovery period. Groundwater withdrawal from wells PW07 and PW08 during the first 2 hours of recovery, and over the next several days, likely affected recovery-period water levels measured in site shallow-aquifer monitoring and deep-aquifer wells. Little measurable effect was observed, however, because of the low frequency of water level measurement during the recovery period and the water rise due to rain on October 25. Nevertheless, water levels were observed to recover to their pre-test levels, reflecting normal facility operation pumping conditions.

5.2.3.2 Water Level Monitoring

Background water level data were collected before the aquifer test to help assess pre-test water level trends. Water level measurements were collected in two ways:

- Water levels were measured manually every day (using an electric water level indicator at each observation and pumping well location). The frequency was adjusted during the test based on the aquifer response at each monitoring location.

- Data loggers with pressure transducers were installed in 16 shallow and deep observation wells and the Columbia River. Manual measurements in these wells confirmed data logger measurements.

Table 5-7 lists the wells in which water levels were monitored using data loggers. In addition to the deep aquifer and offsite monitoring locations, the following areas at the site had a data logger that monitored water levels in the shallow aquifer: scrap yard, south landfill, north landfill, and south wetlands. During the test, the frequency of data collection for the data loggers was modified based on the proximity of the monitoring well to the pumping wells, and on changes in the observed water level response in the monitored well. The frequency of data collection for the data loggers was modified again before the aquifer test was stopped.

Table 5-7 Data Logger Monitoring Network for Multiple-Well Aquifer Test			
Data Logger No.	**Channel 1**	**Channel 2**	**Channel 3**
1	Fairview Farms #4	—	—
2	Fairview Farms #6	—	—
3	PW16	Atmospheric	MW15
4	PW06	PW04	—
5	MW02-24 (formerly MW02)	MW13	—
6	MW18-16	MW18-31	—
7	MW16	MW19	—
8	MW21-25 (formerly MW21)	MW21-14 (formerly TMW07)	—
9	MW06	—	—
10	PW17	—	—
11	Columbia River	—	—

Water level measurements were collected manually at the following monitoring locations:

- Shallow groundwater monitoring wells MW01 through MW26
- Production wells PW04, PW05, PW06, PW08, PW09, PW11, PW12, PW16, PW17, and PW18
- Offsite irrigation wells Fairview Farms #4 and #6
- Columbia River
- Company Lake

In addition to the monitoring locations described above, the City of Portland (COP) Water Bureau provided water level data for four production wells (wells #12, #13, #18, and #19) located west of the site in the eastern portion of the Columbia South Shore Wellfield. Water levels from COP wells were collected hourly using data loggers and provided to CH2M HILL in electronic format. A location map, drilling logs, and general well construction information for the COP wells are provided in Appendix C-4. DEQ and EMCON Northwest, Inc. provided access to four monitoring wells southwest of the site (Oregon DEQ wells DEQ-4s and DEQ-4d, and Cascade Corporation wells 29-DS and 29-DG). Water levels in these four wells were measured twice daily during the aquifer test. Table 5-8 contains general well construction information for these four wells (information provided by EMCON Northwest, Inc., November 1995). Approximate locations are given in Figure 5-15.

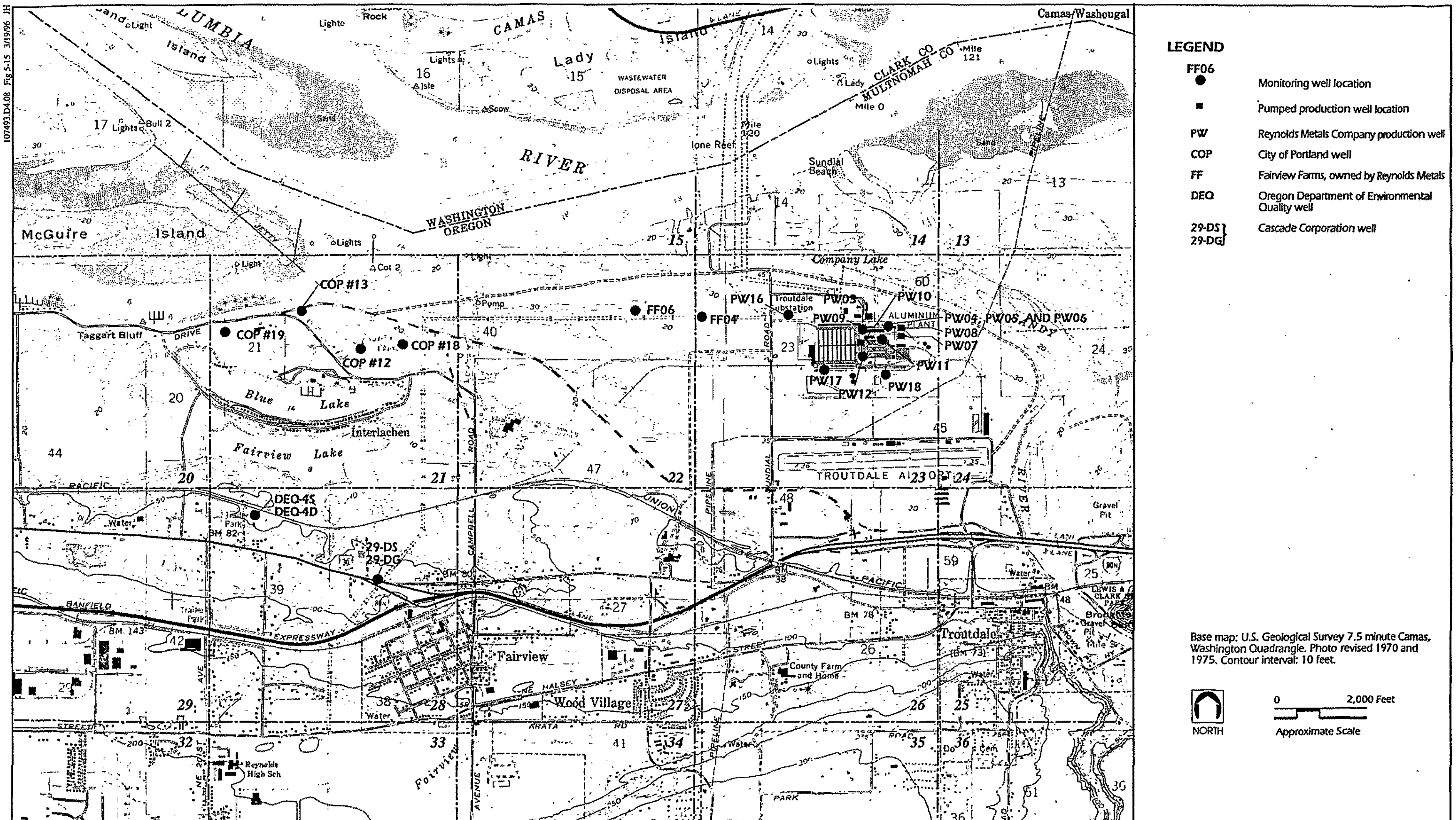

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Figure 5-15
PUMPING WELLS, DEEP WELLS, AND OFFSITE WELLS MONITORED FOR MULTIPLE-WELL AQUIFER TEST
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
Conceptual Hydrogeologic Model Report

CH2M HILL

Analysis of estimated drawdown in deep-aquifer wells extending from the RMC site west toward the COP Columbia South Shore Wellfield indicates that hydraulic influence in the multiple-well aquifer test was observed as far west as well FF06, approximately 1 mile west of the pumping center at the site. Such influence was not observed, however, at the COP production wells located near the eastern end of the Columbia South Shore Wellfield, at least in a test of this duration. The response to pumping at the RMC facility can be estimated to have propagated approximately 8,000 feet to the west of the facility. This radius of influence was estimated for the area west of the facility only. The actual distance from the facility that drawdown can be observed will vary with direction, depending on:

- The magnitude and direction of the background horizontal hydraulic gradient and flow direction
- Changes in aquifer thickness or permeability
- Changes in the degree of hydraulic connection with nearby surface water bodies
- The duration of the aquifer test pumping period

Good hydraulic connection between the Columbia River and the deeper portion of the aquifer was observed in most wells where the influence was not overwhelmed by the response to pumping. Shallow water levels were also observed to respond to Columbia River stage changes, although the magnitude of the shallow response was dependent on distance from the river and on the presence of low-permeability sediments. At most locations, it was necessary to manipulate the river stage and water level elevation data before the presence of a response to pumping could be determined, because the response to river stage changes was greater than the estimated response to deep-aquifer pumping.

Because the groundwater pumping rate for this aquifer test exceeded RMC's average full-production-capacity water demand of 1,800 gpm by approximately 50 percent, the hydraulic response to normal operating conditions at the RMC-Troutdale facility is likely to be more limited than that observed in this test. However, increased duration of pumping may result in an observed response at locations that did not respond in this test.

Water Quality. Groundwater samples were collected from each production well approximately every 2 hours for field measurements of temperature, electrical conductivity, and pH. These data are included in Appendix C-5. The measured field parameter values for the four production wells remained relatively constant for the duration of the aquifer test. Groundwater sampling data sheets and laboratory analytical results of the fluoride analyses are included in Appendix C-5. Table 5-9 lists the fluoride analytical results for the production well samples collected during the test.

Table 5-9 Laboratory Analytical Results: Production Well Fluoride Sampling			
Well	**Date/Time Sampled**	**Fluoride (mg/L)**	**Qualifier**
PW03	10/23/95 08:05	0.29	
	10/25/95 18:00	0.31	
PW07	10/23/95 08:10	0.25	U
	10/25/95 18:00	0.25	U
PW08	10/23/95 08:10	1.1	
	10/25/95 18:00	1.4	
PW10	10/23/95 08:15	0.25	U
	10/25/95 18:00	0.25	U

U = not detected above the laboratory detection limit of 0.25 mg/L
mg/L = milligrams per liter

Fluoride concentrations at PW07 and PW10 remained below the detection limit and were therefore not observed to vary during the test. At PW03 and PW08, the fluoride concentrations were observed to increase 0.02 mg/L (a 7 percent increase) and 0.3 mg/L (a 27 percent increase), respectively. Whether the slight increases represent an actual concentration increase in the samples, or whether the variability falls within the limits of error for the sampling and analytical methodology, is unknown.

Field measurements of TSS, DO, temperature, pH, and electrical conductivity at the Company Lake outfall monitoring station were collected periodically during this test. Field data sheets and tabulated data are contained in Appendix C-6. No trends were apparent for the measured parameters during the monitoring period. Field measurements of TSS were highly variable, ranging between -10 NTU and 170 NTU. Dissolved oxygen measurements were also variable, ranging between 10.0 mg/L and 14.3 mg/L. Water temperature ranged between 13 and 17 degrees Celsius. Field pH ranged between 8.2 and 8.4, and electrical conductivity ranged between 0.25 and 0.49 milliSieman.

5.2.3.4 Water Level Response to Pumping

Distance-Drawdown Analysis for Deep-Aquifer Wells West of the Facility. This portion of the multiple-well aquifer test data analysis assesses the measurable influence of the groundwater withdrawal at the RMC site on water levels west of the site. Estimated drawdown observed in wells west of the site will be used to assess the potential for pumping at the RMC site to affect water levels in aquifers in other areas.

The westward extent of deep-aquifer pumping influence during the multiple-well aquifer test was estimated using water levels observed in the following wells:

- PW06

- PW16
- Fairview Farms #4
- Fairview Farms #6
- COP Well #18

Construction details for the RMC production wells and the Fairview Farms wells used in this analysis are listed in Table 5-5. The well log of COP #18 is provided in Appendix C-4. Figure 5-15 provides the approximate location of each well.

Atmospheric pressure changes were relatively minor (less than 0.1 ft) during the first 48 hours of the aquifer test (Figure 5-16). At approximately 10:00 a.m. on October 25, the atmospheric pressure began decreasing (approximately 0.35 ft over the next 12 hours) in response to the approaching storm that ended the test. Because of the relatively small changes in atmospheric pressure during the majority of the aquifer test, no atmospheric pressure corrections were applied to the water level data collected in shallow or deep groundwater monitoring wells.

Water level data from the five deep-aquifer monitoring wells analyzed exhibit variability related to Columbia River stage fluctuations. Seasonal fluctuations that result in long-term (greater than one month) increases or decreases in river stage elevation were not observed during the multiple-well aquifer test because of the focused data collection period. The observed Columbia River stage fluctuations were caused by:

- Tidal influence, resulting in approximately two water level peaks and two water level lows per day

- Bonneville Dam releases or precipitation events resulting in increasing or decreasing river stage trends approximately 3-7 days in length

The response to river stage fluctuations created a variable, or "noisy," data set that required smoothing or filtering before the response to the aquifer test could be assessed. As described below, the method selected for smoothing was to apply a 24-hour moving average to the Columbia River data set to remove the response to tidal fluctuations that occurs at a higher (daily) frequency. If a comparison of water level changes in observation wells to longer-term Columbia River stage changes indicated that the groundwater levels had been affected by pumping, a river efficiency (the ratio of aquifer response to river response) (Walton, 1970) was calculated and the water level data were corrected for river stage fluctuations to produce an estimated actual drawdown. The following sections describe the method for producing the drawdown estimates at each well location used in the distance-drawdown analysis.

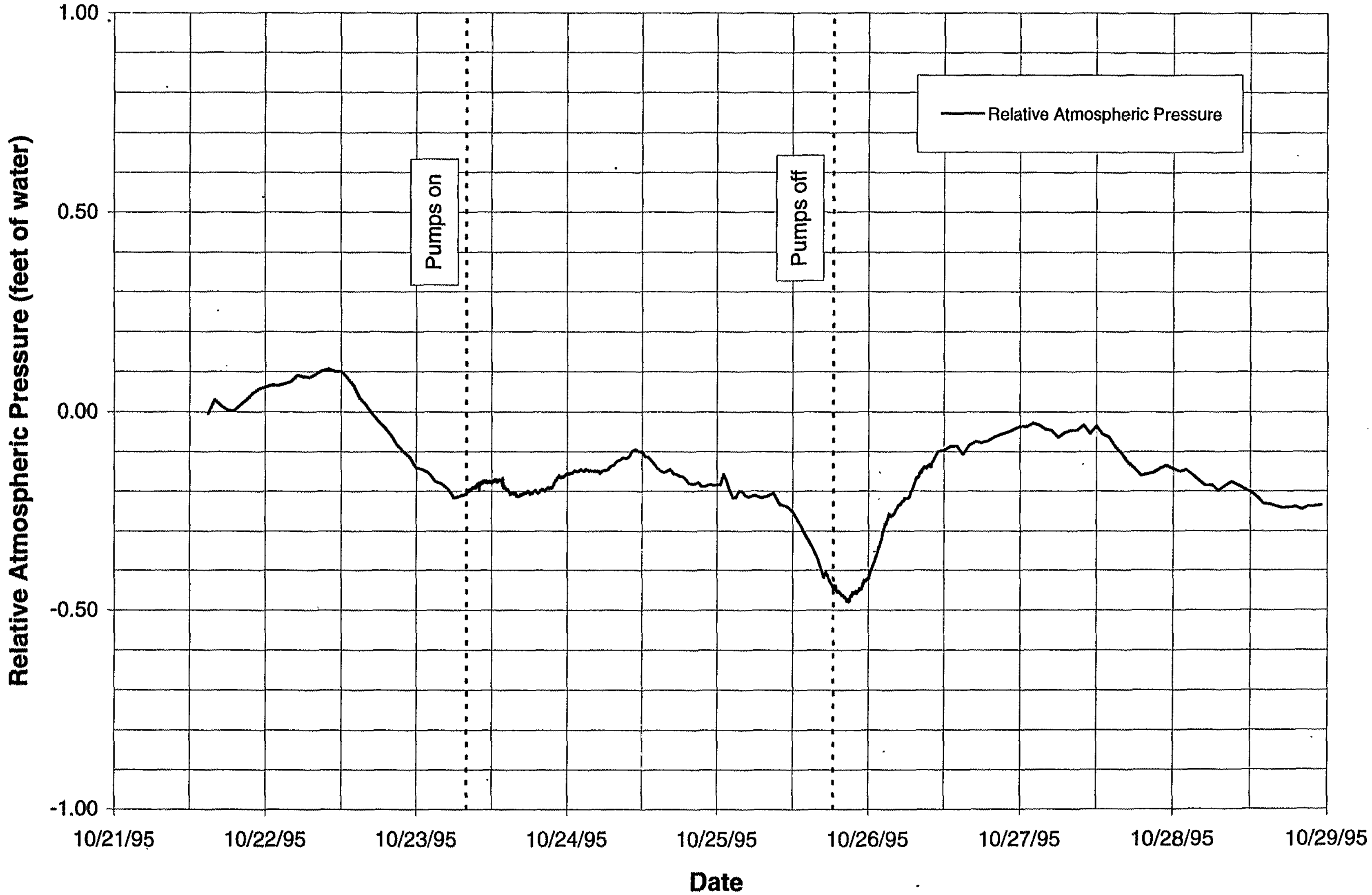

Figure 5-16
Relative Atmospheric Pressure
Reynolds Metals Company
Troutdale, Oregon

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PW06. Production well PW06 is located between pumping wells PW03, PW07, and PW08 (Figure 5-15). Hydrographs for PW06 and the Columbia River from October 21 through October 31 are presented in Figure 5-17. An approximate 14.5-ft decline in PW06 water levels occurred following the start of the aquifer test, and appeared to approach an equilibrium water level elevation of -8.00 ft (1929 NGVD) on October 24, near noon. This equilibrium water level persisted for approximately 30 hours before the end of the test. Water levels recovered more than 80 percent over the next 5 hours, to an elevation of 3.00 ft.

The Columbia River data in Figure 5-17 show the daily tidal fluctuations that occurred during the aquifer test, superimposed on the longer-term increases and decreases in river stage that are apparent after a 24-hour moving average has been used to smooth the data. The 24-hour moving average for a given time (t) was calculated by computing the arithmetic average of water levels for times (t), (t-1), (t-2), ..., (t-11), and times (t+1), (t+2), ..., (t+12). Moving averages were applied to water level data by Erskine (1991) and Serfes (1991) to remove the influence of tides. The smoothing provides a better basis for the estimation of average river stage elevation during the aquifer test and helps identify any trends in river stage (other than tides) that may have affected the water levels in PW06. The smoothed Columbia River stage data show that the river stage was increasing from approximately 6.6 to 6.8 ft when the aquifer test began, remained relatively constant through October 24, and then began increasing on October 25 from approximately 6.8 to 7.6 ft by the end of the test.

On the basis of an initial water level elevation of about 6.5 ft, and an equilibrium water level elevation of approximately -8.0 ft, the estimated drawdown in PW06 due to the aquifer test was calculated to be 14.5 ft. Not enough background data were collected to assess the water level response to river stage fluctuations at PW06. However, the river stage changes in tenths of feet appear to be insignificant relative to the observed 14.5 ft of drawdown; therefore, the PW06 drawdown estimate was not corrected for river stage fluctuations.

PW16. Figure 5-18 presents the water level measurements from PW16 and the Columbia River for October 1995. Because of the variability in the Columbia River data set caused by the daily tidal fluctuations, it was necessary to smooth the Columbia River data set to help clarify longer-term river stage trends that could more easily be compared with the trends in the PW16 data set. Elevation changes in the PW16 data set generally mimicked the longer-term variations observed in the Columbia River data; the daily tidal fluctuations were not observed. Two downward spikes occurred in the PW16 data on October 26 and 28. The cause of the intermittent anomalous low water levels is unknown. Because RMC pumping was held constant during this period, these downward spikes may be the result of pumping at the nearby BPA cooling water well at the BPA substation adjacent to the RMC facility.

The PW16 data set was relatively smooth prior to applying a 24-hour moving average; thus, the smoothed data differed only slightly from the raw data. To assess whether water levels at PW16 responded to pumping during the aquifer test, the groundwater elevation changes that were expected to result from river stage changes had to be compared with actual observed groundwater elevation changes. A difference between the observed and predicted

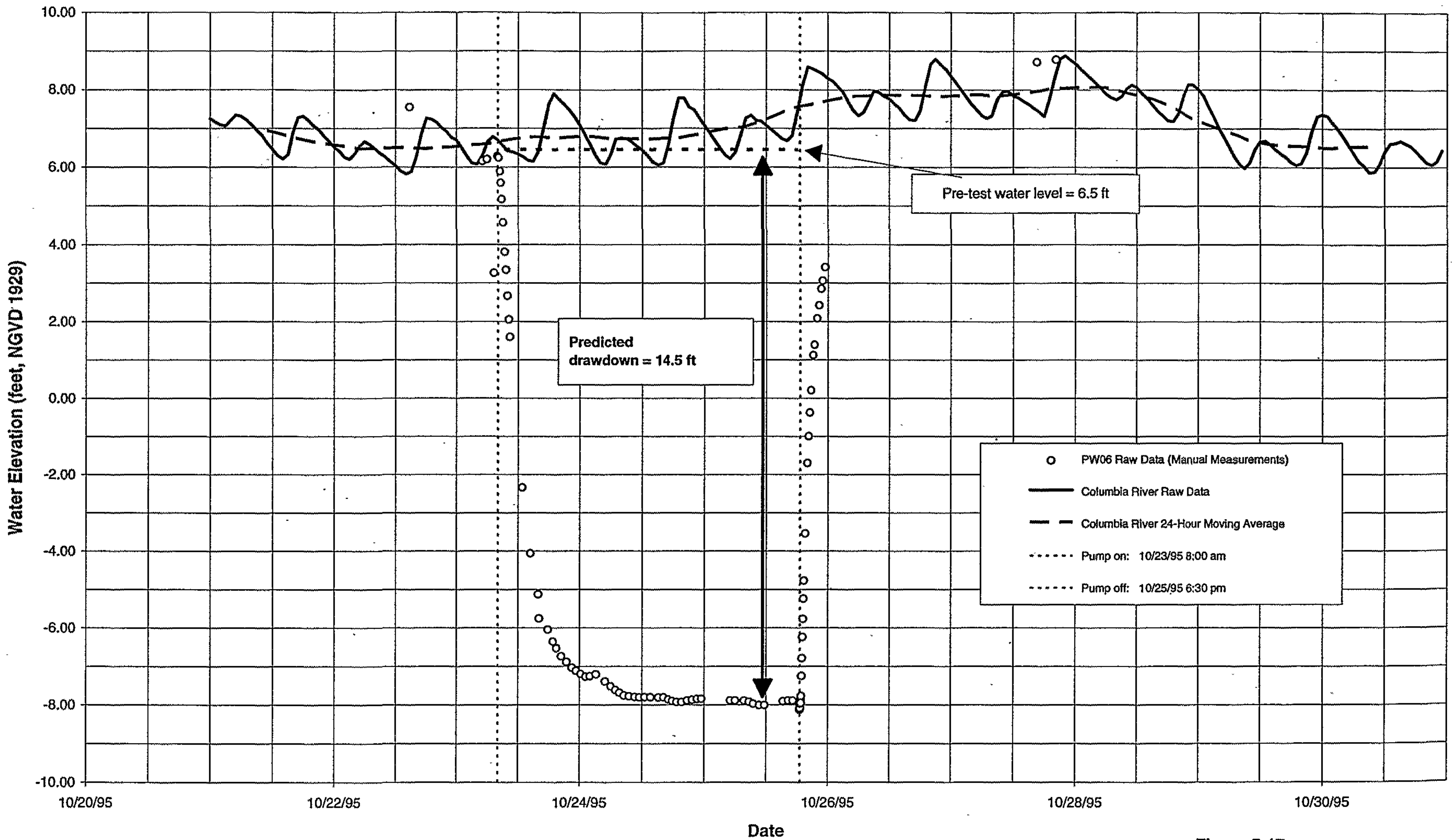

Figure 5-17
PW06 Drawdown Estimate
Multiple Well Aquifer Test
Reynolds Metals Company
Troutdale, Oregon

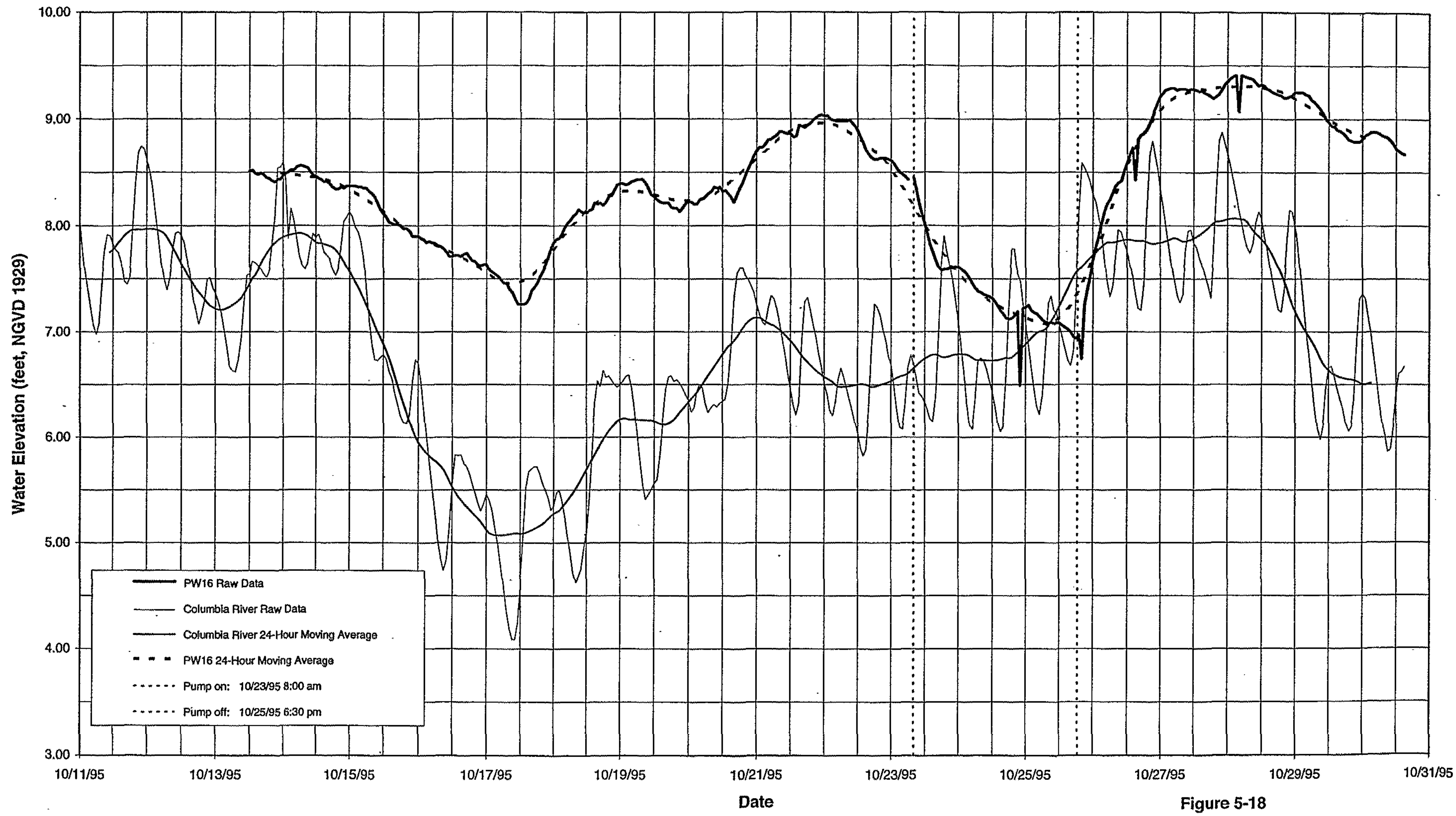

Figure 5-18
PW16 Hydrograph
Multiple Well Aquifer Test
Reynolds Metals Company
Troutdale, Oregon

groundwater elevation responses would be attributable to the aquifer test, although other system stresses that could affect water levels could have been present during the same period.

Although the PW16 water levels are observed responding to nontidal river stage fluctuations in Figure 5-18, the response in the aquifer appears delayed with respect to the river stage changes. To facilitate comparison of the water level response at PW16 with the Columbia River stage fluctuations, the smoothed Columbia River data set was shifted forward in time (along the Date axis) until individual river stage peaks and troughs reasonably corresponded to groundwater elevation changes, a shift forward of approximately 26 hours. The shifted and smoothed Columbia River data are compared with the smoothed PW16 water level data set in Figure 5-19.

The forward shift in the Columbia River data is not necessary for analysis, but it facilitates a visual comparison of individual peaks and troughs of PW16 and the Columbia River water level data. Erskine (1991) applied a time lag to bring monitoring well water level and tidal level data sets in phase. The time lag was based on a least-squares fit method, with visual inspection used for confirmation that the two data sets were in phase.

Two approaches were used to estimate the forward shift for the smoothed Columbia River data: statistical and visual. The statistical approach consisted of choosing a subset of the two 24-hour moving average data sets with the following criteria:

- The subset was selected either before or after the multiple-well aquifer test.
- The subsets were visually similar.
- No other significant stress to the system was apparent.

The 2-day time period of the data set chosen for the statistical comparison of river stage and PW16 groundwater elevation data was October 21 through October 22. A correlation coefficient was calculated for various time shifts, ranging from zero hours to 30 hours. The maximum correlation coefficient (0.98) was achieved with a 20-hour phase shift. However, a visual comparison of the 24-hour moving averages of the PW16 data and the 20-hour shifted Columbia River data showed that the October 22 water level peak for the shifted Columbia River data set occurred approximately 6 hours prior to the same peak occurring in the PW16 data set. To better align the two 24-hour moving average data sets, the Columbia River phase shift was increased from the statistically based 20 hours to a visually based 26 hours. It should be noted that the primary purpose of shifting the Columbia River data was to make visual comparisons easier and to help determine whether other stresses were being exerted on the system. The two data sets do not need to be in-phase to calculate a river efficiency coefficient.

Not all trends in the smoothed and shifted Columbia River data are present, or in phase with, the smoothed PW16 data, confirming that stresses other than the Columbia River affect water levels at this location. Increased pumping at the RMC facility between September 26 and October 17, 1995, may have eliminated the October 14 water level peak from the PW16 data. Resuming normal pumping on October 17 may have caused the water level increase

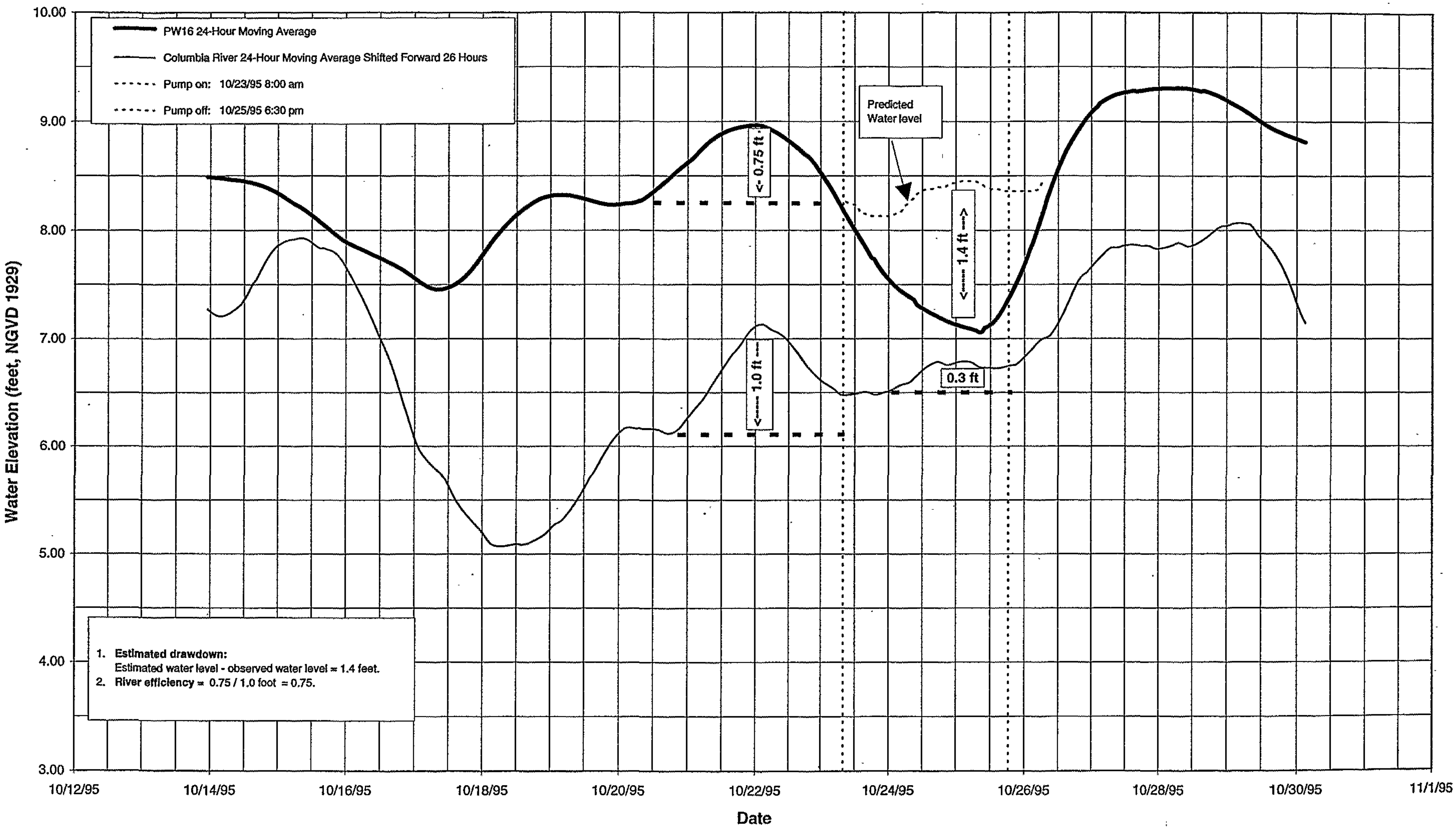

Figure 5-19
PW16 Drawdown Estimate
Multiple Well Aquifer Test
Reynolds Metals Company
Troutdale, Oregon

in PW16 beginning early on October 18, thus making the water level changes in PW16 correlate better with Columbia River stage fluctuations.

As shown in Figure 5-19, a river efficiency of the aquifer near PW16 (the ratio of groundwater elevation change to corresponding river stage change) was estimated by use of the ratio of the October 22 PW16 water level peak (0.75 ft) and the smoothed Columbia River water level peak (1.0 ft). The estimated river efficiency coefficient is 0.75. Erskine (1991) estimated a tidal efficiency using the ratio of the standard deviation of the tidal data and the monitoring water level data. This method is preferred to using the ratio of individual peaks because it reduces the effect of individual reading errors, but it is strictly applicable only for identically formed signals symmetrical about their mean with continuous reading. The fluctuations observed in the Columbia River and PW16 water level data are not symmetrical about their mean because longer-term trends in water levels were present during the period of monitoring.

Although the October 22–25 water level decline observed in PW16 water levels began prior to the aquifer test, the downward trend (decreasing an additional 1.1 ft) in PW16 continued for approximately 48 hours after the river began an increasing trend on October 23, rising 0.3 ft over the next 36 hours. If the aquifer was not influenced by other factors, the water level in PW16 would have been expected to rise approximately 0.2 ft (based on the estimated 0.3-ft river stage increase and the calculated river efficiency of 0.75) instead of continuing its gradual decline. It is likely that the 0.2-ft PW16 water level rise resulting from the 0.3-ft river stage rise was transmitted to the aquifer, but it is superimposed on a steeper declining water level trend observed in PW16 in response to pumping at the facility.

To estimate the actual response to pumping at PW16, the river efficiency estimate was used to create a data set that represented the water level change that would have occurred at PW16 in response to the river stage rise only. Beginning at the start of the aquifer test, the river stage change was corrected by multiplying it by the river efficiency estimate to create the "predicted" PW16 water level trend. The resulting line represents the estimated water level trend that would have been expected without the influence of pumping. The predicted water level assumes that the PW16 water level is responding only to Columbia River stage fluctuations during this period of time. The presence of stresses other than the river or the aquifer test could introduce error into the predicted water levels.

The difference between the observed and predicted response represents the response to pumping (drawdown). The maximum observed drawdown at PW16 is estimated to be 1.4 ft (see Figure 5-19), approximately 0.3 ft more than would have been predicted if the lowest water level during the test had simply been subtracted from the water level at the beginning of the test.

Fairview Farms Well #4. Hydrographs for Fairview Farms #4 (FF04) and the Columbia River from October 12 to November 1 are presented in Figure 5-20. Unlike PW06 and PW16, the influence of the Columbia River daily tidal cycles is evident in FF04 water levels. In general, the two daily tidal cycles seen in the river hydrograph appear muted and combined into a single daily cycle at FF04. A longer-term Columbia River stage decline

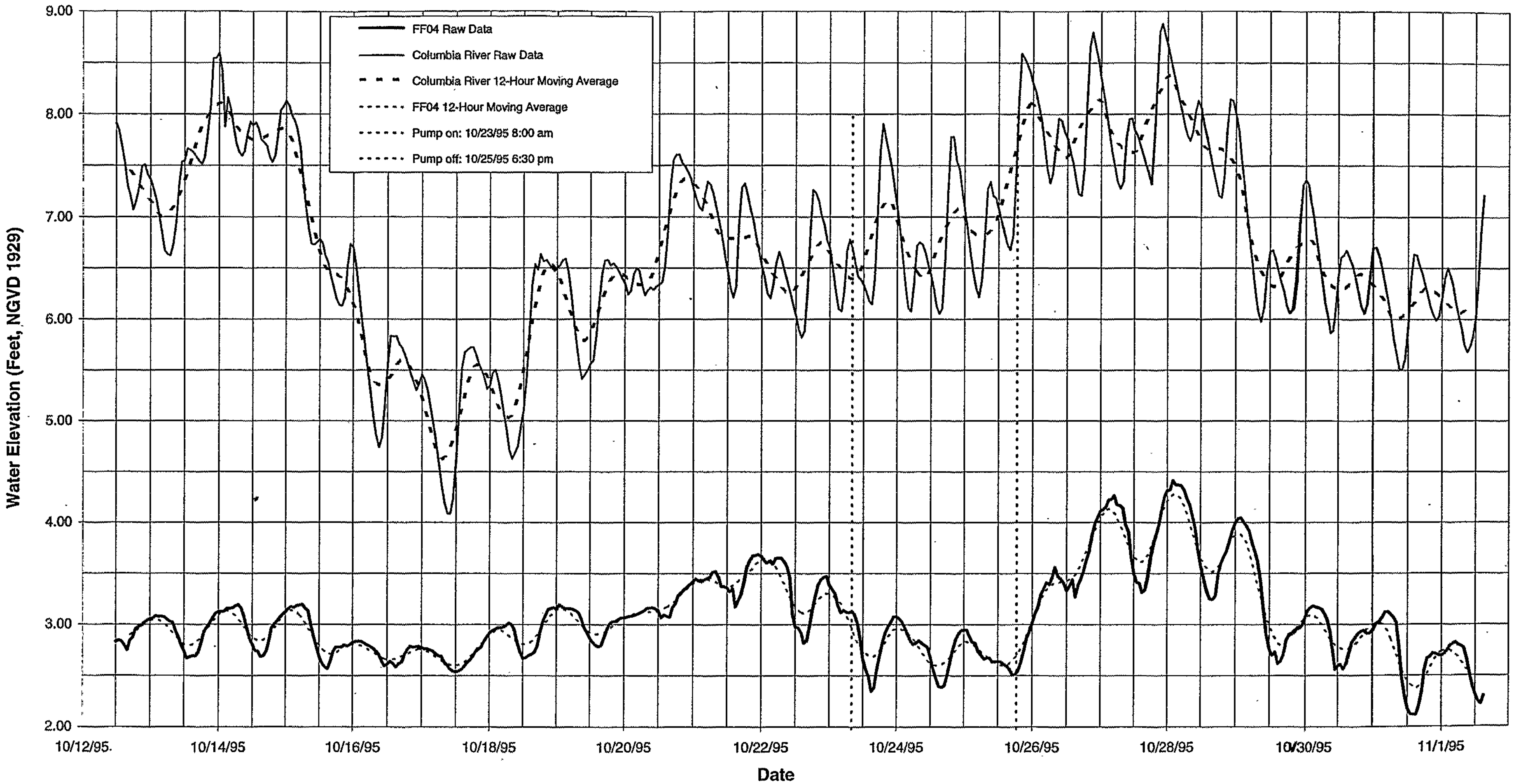

Figure 5-20
Fairview Farms #4 Hydrograph
Multiple Well Aquifer Test
Reynolds Metals Company
Troutdale, Oregon

beginning October 15 and ending October 17 is not apparent in FF04 water levels, yet longer-term river stage increases and declines from October 21 to November 1 are observed in the FF04 water levels. The magnitude of the FF04 water level response to river stage fluctuations also appears to increase with time, suggesting that the river efficiency coefficient increases with time for this period.

To make the river data more comparable to the groundwater elevation data set, a 12-hour moving average was used to smooth the Columbia River data. Unlike the 24-hour moving average used to remove tidal fluctuations from the river data at PW16, the 12-hour moving average smoothed the twice-daily tidal variation observed in the Columbia River data set into one cycle that more closely resembled the FF04 raw data. To remove minor fluctuations from the FF04 groundwater elevation data set, the same 12-hour moving average was applied. Because the data were fluctuating on a roughly 12-hour cycle, this resulted in little change from the raw data.

To develop a correlation coefficient for assessing the appropriate amount of time to shift the Columbia River data to bring individual river stage fluctuations into alignment with corresponding groundwater elevation changes, a subset of both data sets from October 26 to November 1 was used to calculate a correlation coefficient. A correlation coefficient was calculated between the data subset of the smoothed Columbia River and FF04 data for time shifts ranging from zero to 30 hours. The maximum correlation coefficient (0.84) was achieved with a 26-hour shift. The 26-hour shift can also be confirmed by a visual comparison of the two 12-hour moving average data sets in Figure 5-20.

The river and groundwater elevation data, smoothed with a 12-hour moving average, still exhibit daily tidal fluctuations. Therefore, assessing the response of the aquifer to the aquifer test appears difficult, if at all possible. To remove the daily fluctuations, a 24-hour moving average was applied to smooth both the river and the FF04 data sets. These smoothed data, with the river stage data shifted forward 26 hours, are presented in Figure 5-21. By removing the daily fluctuations, longer-term trends in the water levels are more apparent. Using the same method described for PW16 and the October 28 water level peak, a river efficiency coefficient was estimated. The resulting river efficiency estimate is 0.78, similar to the estimated river efficiency coefficient for PW16 (0.75).

In a manner similar to that used to estimate drawdown at PW16, the river efficiency was estimated and used to predict a water level response without the effects of pumping. The difference between the predicted water level trend and the observed water level trend is assumed to be the sole result of pumping at the facility, and is therefore labeled drawdown. Figure 5-21 shows the trend locations and estimated values used to arrive at an estimated peak drawdown of 0.24 ft.

The recovery portion of the FF04 observed water levels following the end of the aquifer test appears to be increasing at approximately the same rate as the Columbia River stage, in contrast to the more rapid increase observed at PW16. Because the response to pumping at FF04 was approximately 1.2 ft less than that at PW16 (an 83 percent decrease), a diminished response to recovery was also expected.

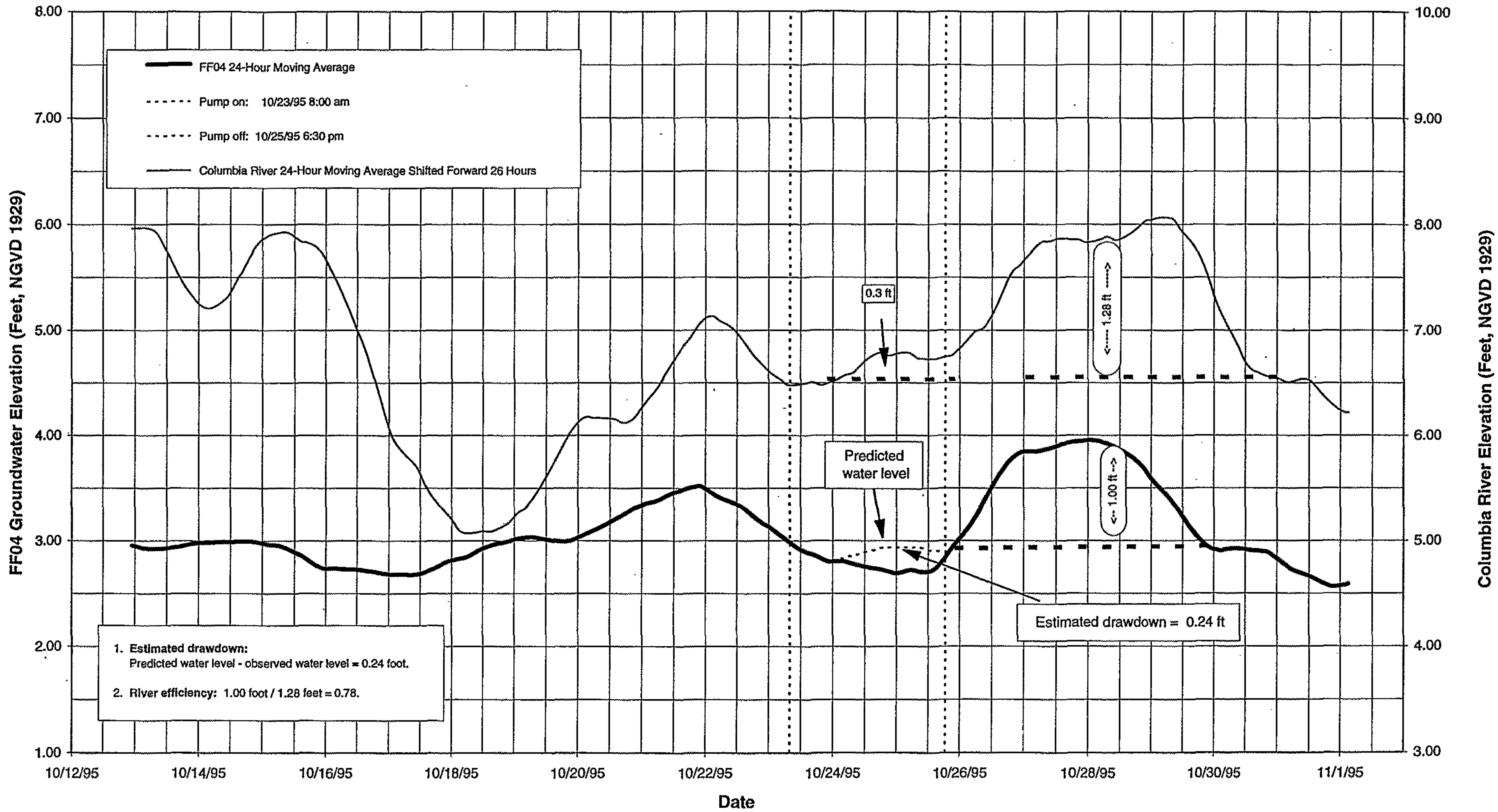

Figure 5-21
Fairview Farms #4 Drawdown Estimate
Multiple Well Aquifer Test
Reynolds Metals Company
Troutdale, Oregon

Fairview Farms Well #6. The groundwater elevation response to river stage changes at FF06 is very similar to the response observed at FF04. Therefore, the analysis conducted on the FF04 water level data set to estimate a river efficiency coefficient and a drawdown was applied to the FF06 water level data. Figure 5-22 presents smoothed and shifted Columbia River data and FF06 data for October 14 to November 1, 1995. Water level data for FF06 were not collected October 21–23 because of a data logger malfunction.

A 12-hour moving average of both data sets was taken, and correlation coefficients of a data subset (October 26-29) for various shifts of the Columbia River were calculated. A maximum correlation coefficient of 0.53 was obtained with a 26- and 27-hour time shift. A visual comparison of the 26-hour shifted data indicated that the two sets of water level data were in phase. The slightly decreased correlation between the aquifer and the river may indicate that system stresses (such as pumping) not observed closer to the site affect water levels at this location.

Based on the 24-hour moving average of the Columbia River (shifted 26 hours) and the FF06 data, a river efficiency coefficient of 0.73 was obtained, similar to the river efficiency coefficients estimated for FF04 and PW16.

Water levels in FF06 during the pumping portion of the aquifer test appeared to be relatively constant, even though river stage increased approximately 0.3 ft during this same period. Because the aquifer at this location is seen to respond to the river before and after the test, the relatively stable water level during the test is believed to reflect a response to the aquifer test. A predicted FF06 water level was estimated based on the 0.3-ft river stage rise and the estimated river efficiency coefficient of 0.73. The difference between the predicted water level and the observed water level yields an estimated peak drawdown of 0.2 ft at FF06, slightly less than the 0.24-ft drawdown estimated at FF04. The exact magnitude of the FF04 and FF06 drawdown is uncertain, but because of the timing, the estimated drawdowns appear to be a result of the multiple-well aquifer test.

City of Portland Well #18. Water level data for COP groundwater production wells in the eastern portion of the Columbia South Shore Wellfield were provided to CH2M HILL by COP staff. The COP #18 data were analyzed because the well is closest to the RMC site. It is located approximately 2 miles west of the site (Figure 5-15), and it is therefore assumed to be the most likely well to respond to the RMC multiple-well aquifer test.

Water level elevation data for the Columbia River and COP #18 for October 12 through 26 are presented in Figure 5-23. There is a higher frequency of the variations in the COP #18 data (than could result from the daily river tides alone), although the magnitude of the variability is relatively small (less than 0.5 ft). The high-frequency variability in the COP #18 water levels was the effect of some other stress (possibly pumping in nearby groundwater production wells).

Twelve-hour moving averages were used to smooth the Columbia River and COP #18 data sets (Figure 5-23). The 12-hour moving average of the Columbia River data combined the two tidal cycles per day into one cycle per day. The 12-hour moving average of the

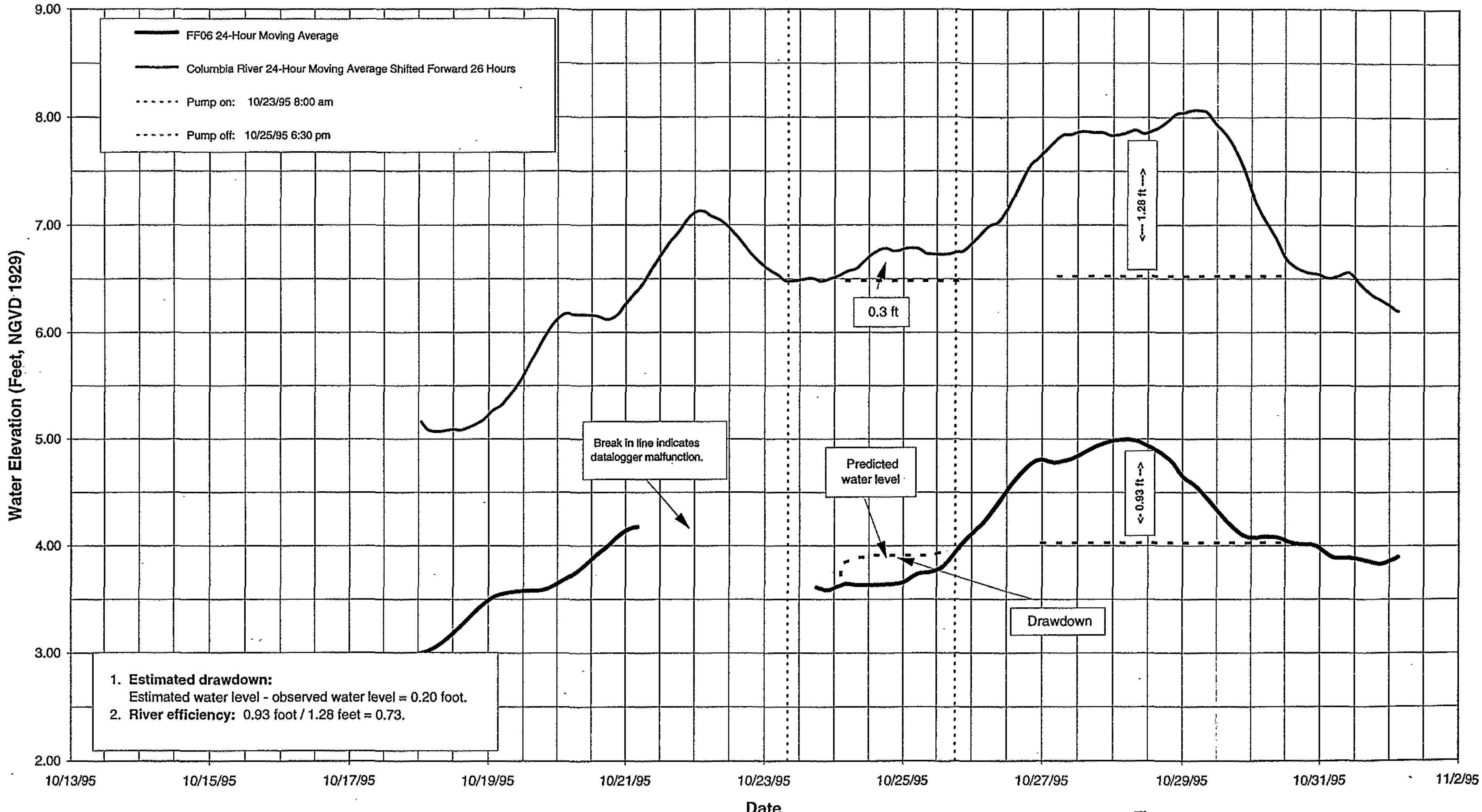

Figure 5-22
Fairview Farms #6 Drawdown Estimate
Multiple Well Pumping Test
Reynolds Metals Company
Troutdale, Oregon

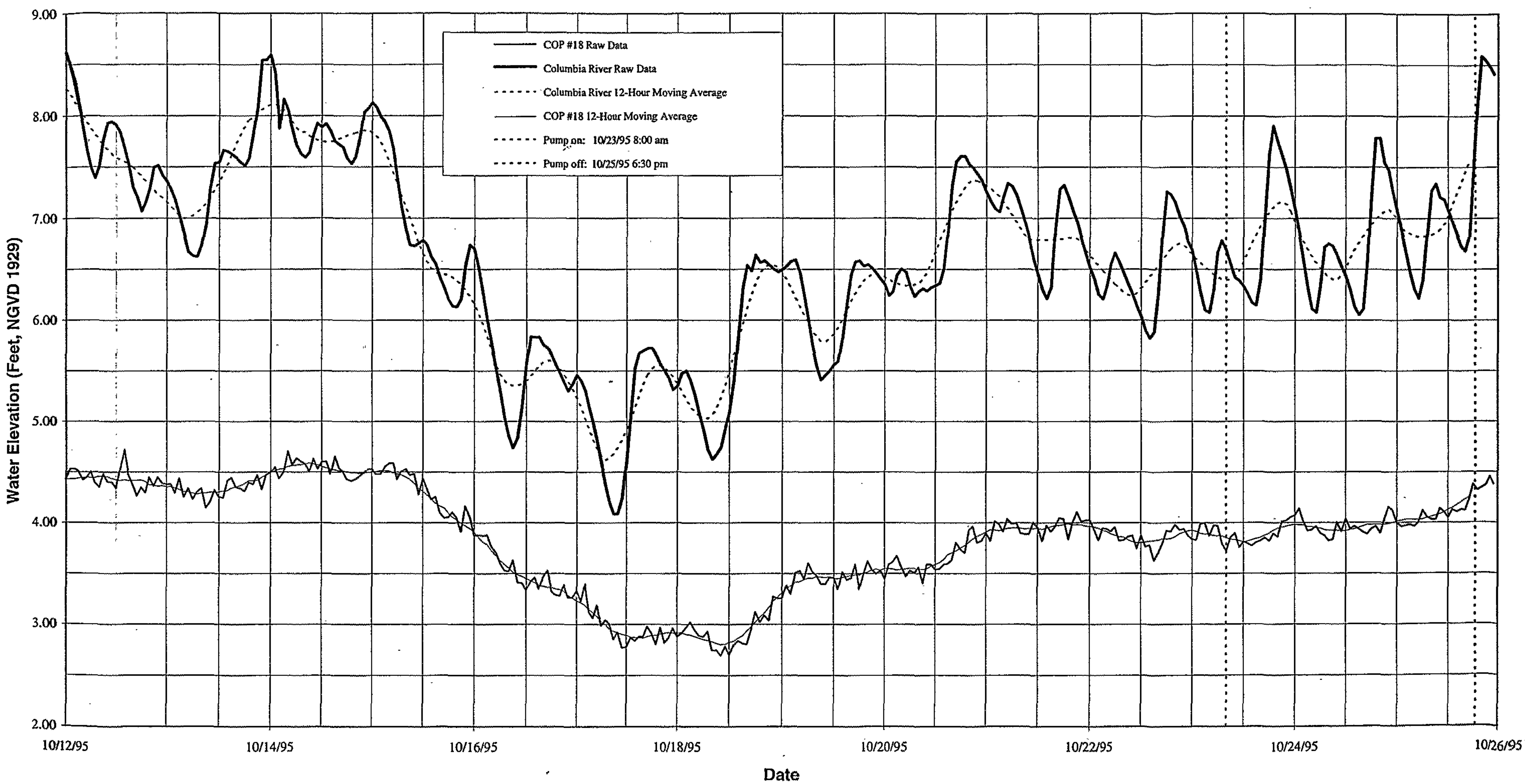

Figure 5-23
City of Portland Well #18 Hydrograph
Multiple Well Aquifer Test
Reynolds Metals Company
Troutdale, Oregon

COP #18 data smoothed the daily variation, leaving only the longer-term water level trends. The entire data set for both the Columbia River and the COP #18 well was used to calculate a correlation coefficient. The correlation coefficient was maximized at 0.95 by shifting the Columbia River data 9 hours forward.

Smoothed and shifted data sets are presented in Figure 5-24. The water level peak on October 14 was chosen to estimate a river efficiency coefficient because it was relatively prominent in both data sets. The estimated river efficiency coefficient for COP #18 is 0.34.

During the RMC multiple-well aquifer test, water levels in both the Columbia River and COP #18 increased. The COP #18 water level gradually increased for the duration of the aquifer test, though the river stage did not. However, when the observed river stage increase of approximately 0.3 ft was multiplied by the estimated river efficiency of 0.34, the predicted groundwater elevation increase of 0.1 ft closely matched the observed increase of approximately 0.1 ft. These data and results indicate there was no measurable response to the RMC multiple-well aquifer test at the COP #18 well. Because no response to pumping was observed at COP #18, and other wells monitored by COP are farther from the RMC site, it is assumed that no response to pumping would be observed at the additional locations monitored, and no analysis of those data was conducted. Hydrographs of the data collected at COP wells #12, #13, and #19 are presented in Appendix C-4.

Measured Groundwater Levels in Cascade Corporation and DEQ Monitoring Wells. CH2M HILL measured water levels in four offsite monitoring wells during the test: two Cascade Corporation wells (29-DS and 29-DG) and two DEQ wells (DEQ-4S and DEQ-4D). Hydrographs and field data sheets for these four wells are contained in Appendix C-7. Although the four wells appear to show a decreasing water level trend, access restrictions to these locations so limited the data collection frequency that an evaluation of baseline water level response was not possible. Therefore, the presence of an aquifer response at these wells resulting from pumping at the RMC site cannot be assessed, although it is unlikely based on the observed response to pumping at nearby locations.

Distance–Drawdown Analysis Summary. Figure 5-25 provides a distance-drawdown plot of the drawdowns estimated at wells PW06, PW16, FF04, FF06, and COP #18. The purpose of the distance-drawdown plot was to help define the hydrogeologic conceptual model, not to quantify aquifer characteristics or draw conclusions about groundwater flow. The magnitude of the estimated drawdown decreased rapidly with distance from the pumping center, which was estimated to be approximately 100 feet west of PW06. The influence of PW10 was weighted less heavily in estimating the location of the pumping center because PW10 is screened significantly deeper than the other three production wells used during the aquifer test (see Table 5-5) and therefore may cause less drawdown in the USA than the other wells. At some distance between FF06 and COP #18, the measurable influence of the multiple-well aquifer test is estimated to be zero. Because no monitoring wells exist between FF06 and COP #18, the exact extent of measurable drawdown in the deep zone resulting from the RMC multiple-well aquifer test is unknown, although it can be estimated to be approximately 8,000 ft.

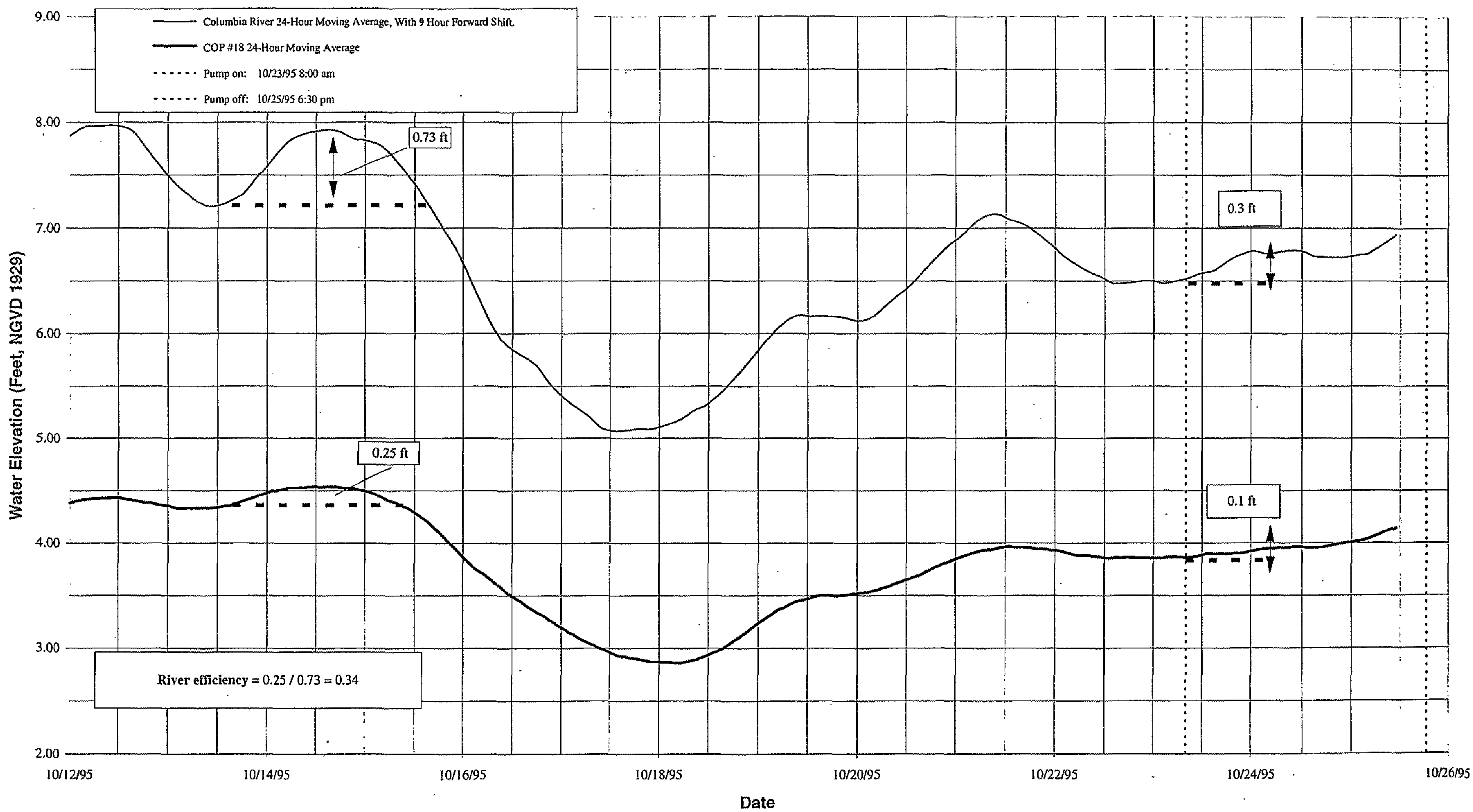

Figure 5-24
City of Portland Well #18 River Efficiency
Multiple Well Aquifer Test
Reynolds Metals Company
Troutdale, Oregon

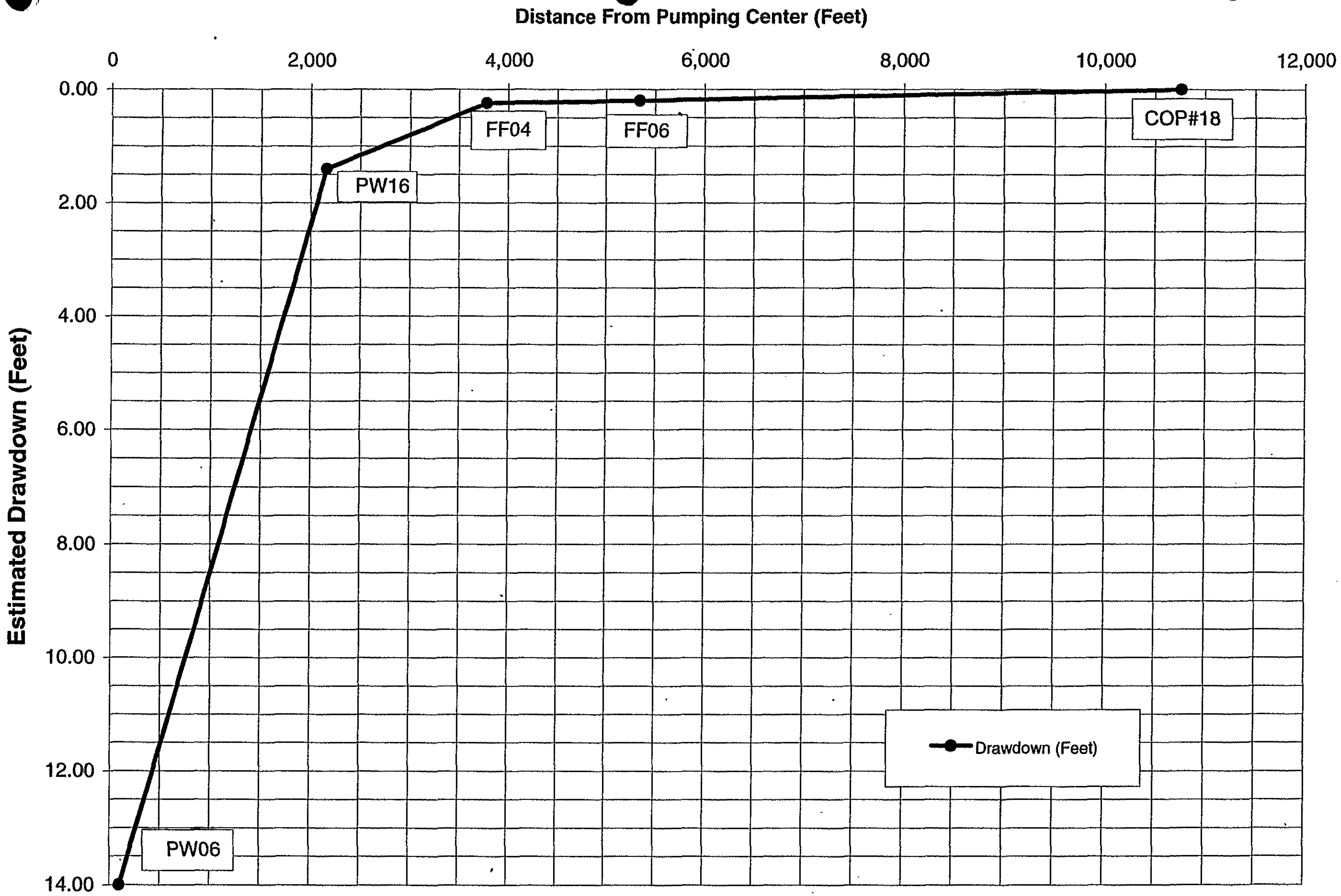

Figure 5-25
Distance-Drawdown Plot
Multiple Well Aquifer Test
Reynolds Metals Company
Troutdale, Oregon

The FF04 single-well aquifer test indicates that the aquifer system is leaky. After the cone of depression spreads to some extent, the water contributed by leakage to the aquifer will equal the well discharge, and the cone of depression will stop increasing in size.

The term "radius of influence" should not be confused with "capture zone." A radius of influence encompasses the area within which response to pumping can be measured, and flow paths are only slightly affected near its perimeter. A capture zone is defined as the area surrounding a pumping well that includes all of the flow paths that converge at the pumping well. Because aquifers always have a hydraulic gradient (i.e., water is flowing through them), the capture zone's width is less than the radius of influence in any aquifer.

Additional Response to Pumping. Measurable drawdown was observed in shallow and deep observation wells in addition to the wells used in the distance-drawdown analysis presented in the preceding section. The water level elevation data from the additional shallow and deep observation wells are evaluated in the following sections for response to the aquifer test using methods similar to those described above.

Shallow Aquifer. Table 5-10 presents the estimated drawdown resulting from the multiple-well aquifer test at each onsite shallow monitoring well observed during the test. Appendix C-8 contains hydrographs of each monitored well, with the Columbia River elevation data set and the estimated drawdown calculations. At shallow wells MW02-24, MW06, MW15, MW18-31, MW21-25, and MW25-35, the groundwater-river stage response was observed and sufficient data were collected to estimate river efficiency coefficients and predicted water level trends. A 0.3-ft average river stage rise during the pumping period was uniformly applied (along with the river efficiency estimate) to correct the observed water level response. The predicted water level is an estimate of what the observed water level in the well would have been if the river stage elevation had remained constant during the aquifer test.

The locations of the monitoring well drawdown estimates listed in Table 5-10 are shown in Figure 5-26. The amount of observed drawdown does not match a simple conceptual model of decreasing drawdown with distance from the center of pumping. This is likely the result of differences in well construction and a heterogeneous aquifer that creates areas of varying hydraulic connection with the deep aquifer. Observed drawdown in shallow monitoring wells ranged from not measurable (wells MW01, MW02-12, MW04, MW05, MW08, MW11, MW14, MW16, MW18-16, MW19, MW21-12, and MW24) to 1.34 ft (well MW18-31). Some wells nearer the pumping center showed no measurable drawdown (MW01, MW02-12, MW14, and MW24), while wells farther away (MW03, MW06, MW09, MW12, MW17-16, MW17-28, and MW18-31) did.

The deeper wells in the scrap yard (MW02-24, MW13, MW25-24, and MW25-35) exhibited more drawdown than nearby shallower monitoring wells, indicating increasing hydraulic connection between the deep aquifer and the shallow aquifer with depth.

Table 5-10
Summary of Drawdown Measured in Shallow Groundwater Monitoring Wells
Multiple-Well Aquifer Test
Reynolds Metals Company

Troutdale, Oregon

Well	Estimated Drawdown (feet)	Drawdown Correction Criteria	Well	Estimated Drawdown (feet)	Drawdown Correction Criteria
MW01	0	1	MW16	0	1
MW02-12	0	3	MW17-16	0.22	3
MW02-24	0.88	2	MW17-28	0.24	3
MW03	0.18	3	MW18-16	0	1
MW04	0	1	MW18-31	1.34	2
MW05	0	1	MW19	0	1
MW06	0.7	2	MW20	0.13	3
MW07	0.11	3	MW21-12	0	3
MW08	0	4	MW21-25	0.15	2
MW09	0.1	4	MW22	0.07	3
MW10	0.15	3	MW23	0.07	3
MW11	0	3	MW24	0	1
MW12	0.33	3	MW25-24	0.55	3
MW13	0.1	3	MW25-35	1.28	2
MW14	0	1	MW26	0.45	3
MW15	0.57	2			

Notes:

Drawdown Correction Criteria:

1. Data suggest no correlation exists between observed water levels and river stage fluctuations at this location. Therefore, the measured drawdowns have not been corrected for river stage fluctuations.

2. The estimated drawdown has been corrected to reflect influence of river stage fluctuations during the aquifer test.

3. Based on measured water level response observed during the aquifer test, no significant correlation between river stage fluctuations and water level changes is apparent. Therefore, any response to river stage fluctuations appears to be insignificant relative to the observed drawdown, and the data has not been corrected.

4. Although measured water level response suggests a possible correlation between river stage fluctuations and water level changes at this location, insufficient data exist to develop a river efficiency coefficient and predicted water level response. Therefore, the measured drawdown at this location has not been corrected to reflect river stage fluctuations.

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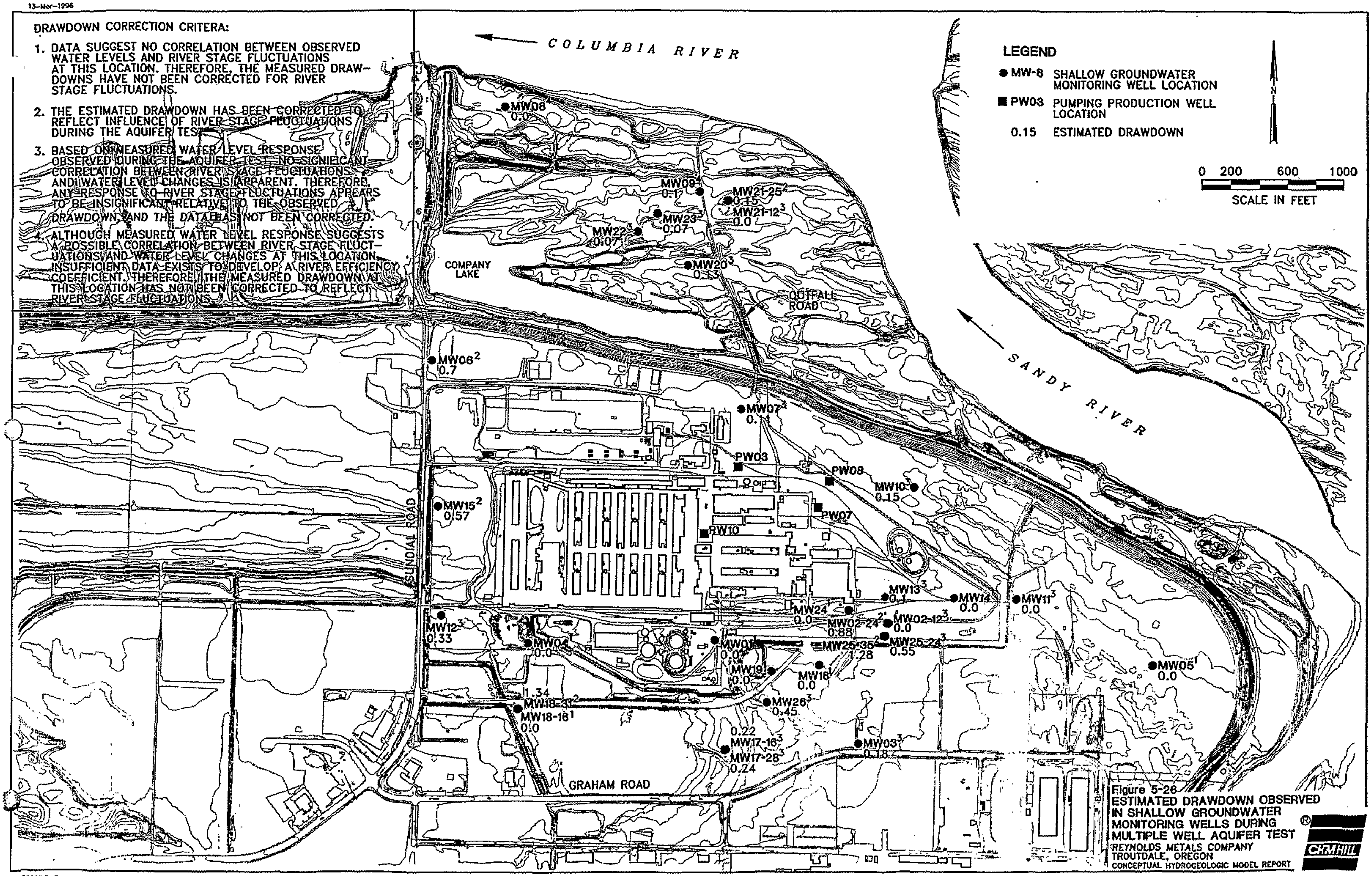

Figure 5-26
ESTIMATED DRAWDOWN OBSERVED IN SHALLOW GROUNDWATER MONITORING WELLS DURING MULTIPLE WELL AQUIFER TEST
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
CONCEPTUAL HYDROGEOLOGIC MODEL REPORT

9293SG23.DWG

Drawdown was observed at both well pair locations in the south wetlands area. Because no drawdown was observed in well MW18-16, the silt encountered during well installation at the MW18 well pair may be thick and continuous enough near MW18-16 to eliminate drawdown at depths less than 16 ft bgs. Drawdowns of 0.33 ft (MW12), 0.57 ft (MW15), and 0.7 ft (MW06) were observed in shallow wells along the western site boundary near Sundial Road. These wells are installed to depths of approximately 25 ft bgs. At this depth there appears to be a relatively uniform hydraulic connection between the deep aquifer and the shallow aquifer along the western site boundary.

Wells north of the dike, except MW08 and MW21-12, exhibited measurable drawdown. MW08 is farthest from the pumping center and nearest to the Columbia River, which may have dampened the response. MW21-12 is screened within a perched zone separated from deeper sand by low-permeability silt. In general, the sand in which wells MW09, MW20, MW21-25, MW22, and MW23 are screened appears to be in hydraulic connection with the deeper aquifer.

In general, all shallow monitoring wells screened at depths near 25 ft bgs except MW05 and MW08 had measurable drawdown resulting from the multiple-well aquifer test. Based on these observations, it appears that shallow groundwater across most of the site can be hydraulically influenced by pumping within portions of the deep aquifer. Shallow monitoring wells screened at depths of less than 25 ft bgs had variable responses to the deep-aquifer pumping. The presence of a response to deep-aquifer pumping at a monitoring well should not lead to the conclusion that shallow groundwater is being transported to the deep aquifer at a specific location. A pressure response to deep-aquifer withdrawals may lower shallow aquifer water levels slightly, without causing a significant deviation from a non-pumping flow path.

Deep Aquifer. Table 5-11 presents the estimated drawdown resulting from the multiple-well aquifer test measured at each deep-aquifer production well monitored during the test. Appendix C-9 contains hydrographs with estimated drawdown for all wells except PW06, PW16, FF04, and FF06, which were described in the previous subsection. The estimated drawdowns for wells PW05, PW06, PW08, PW11, and PW12 were not corrected for river stage fluctuations because the magnitude of drawdown was significantly greater than the observed 0.3-ft river stage rise during the aquifer test. The estimated drawdowns for wells PW17 and PW18 were not corrected for river stage fluctuations because the river stage fluctuations were not observed in water level data collected at these wells. The maximum deep-aquifer drawdown observed was in pumping well PW08 (24.4 ft). The minimum onsite drawdown was in well PW09 and PW16 (1.4 ft), although there is reason to believe PW09 may be obstructed and measurements at this location are inaccurate.

The locations of the deep well drawdown estimates listed in Table 5-11 are shown in Figure 5-27. The amount of observed drawdown seems to generally match a simple conceptual model of decreasing drawdown with distance from the center of pumping, despite the different deep well screened interval elevations.

Table 5-11
Summary of Drawdown Measured in Deep-Zone Observation Wells
Multiple-Well Aquifer Test
Reynolds Metals Company
Troutdale, Oregon

Well	Estimated Drawdown (feet)	Drawdown Correction Criteria	Well	Estimated Drawdown (feet)	Drawdown Correction Criteria
PW01	NM	No Access	PW11	20.5	3
PW02	NM	No Access	PW12	13.5	3
PW03	NM	No Access	PW13	NM	Abandoned
PW04	1.7	3	PW14	NM	NM
PW05	21.5	3	PW15	NM	Decommissioned
PW06	14.0	3	PW16	1.4	2
PW07	NM	No Access	PW17	1.5	3
PW08	24.4	3	PW18	2.0	3
PW09	1.4	1	FF04	0.24	2
PW10	NM	No Access	FF06	0.20	2

Notes:

NM = Not Measured

Drawdown Correction Criteria:

1. Data suggest no correlation exists between observed water levels and river stage fluctuations at this location. Therefore, the measured drawdowns have not been corrected for river stage fluctuations.
2. The estimated drawdown has been corrected to reflect influence of river stage fluctuations during the aquifer test.
3. Based on measured water level response observed during the aquifer test, no significant correlation between river stage fluctuations and water level changes is apparent. Therefore, any response to river stage fluctuations appears to be insignificant relative to the observed drawdown, and the data has not been corrected.

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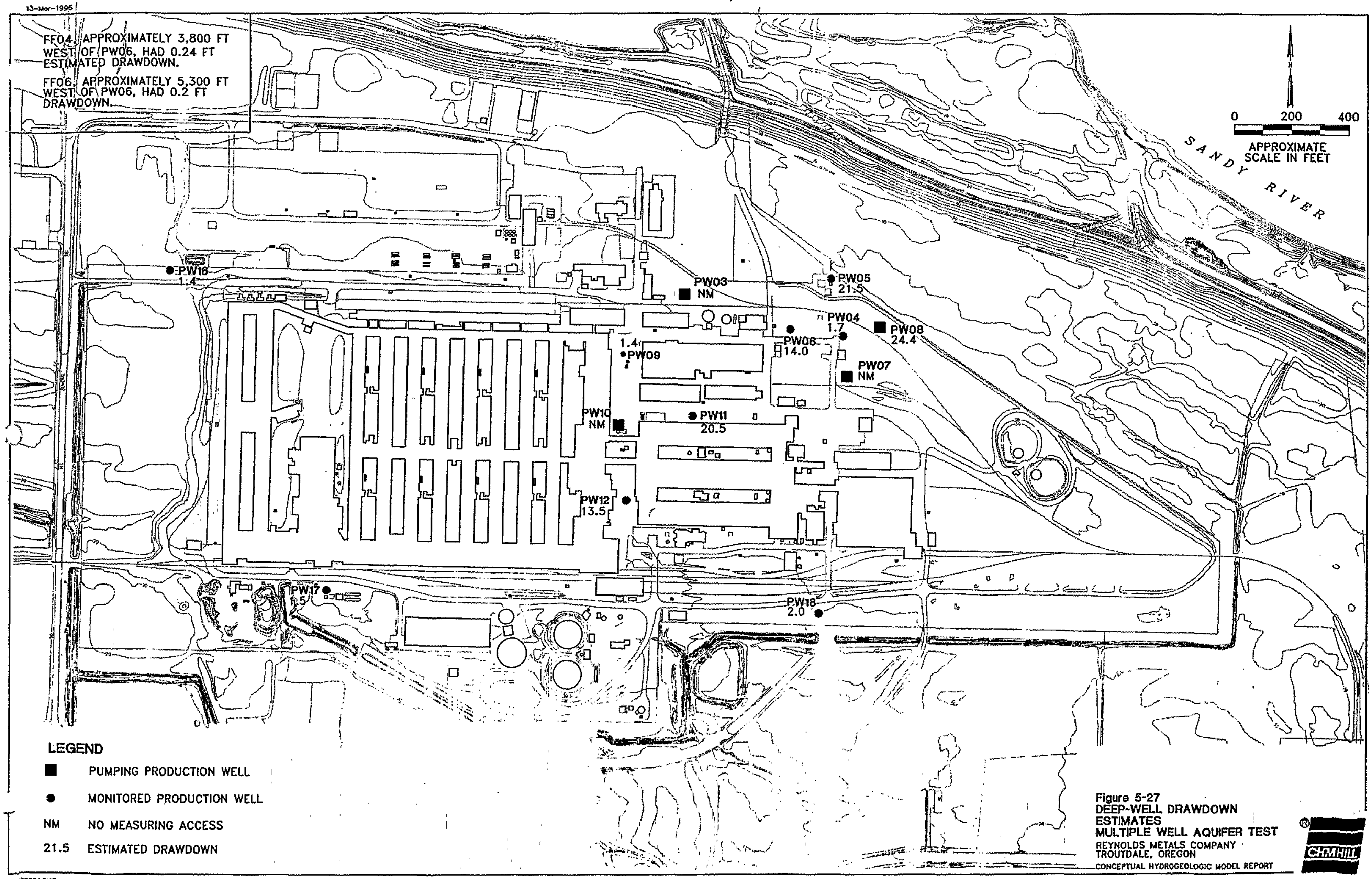

Figure 5-27
DEEP-WELL DRAWDOWN ESTIMATES
MULTIPLE WELL AQUIFER TEST
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
CONCEPTUAL HYDROGEOLOGIC MODEL REPORT

CH2MHILL

9293SG24.DWG

Notable exceptions are at wells PW04, PW06, and PW09. These three wells have been decommissioned by RMC (pumps and pump columns were removed, and a metal plate was welded to the top of the well casing). Downhole videos of these three wells, taken during summer 1995, indicate that the wells are obstructed with sand, silt, or debris to at least the top of the screened interval. The material present within the well screen and casing may mute the expected water level response to the aquifer test.

5.3 Shallow Groundwater Flow Velocity Estimates

Horizontal groundwater flow velocity estimates in the shallow aquifer near the RMC facility range from 0.001 to 1.2 ft/day (0.0003 to 0.366 m/day). These velocity estimates are based on ranges of horizontal hydraulic gradients obtained from groundwater elevation contour maps, on an estimated aquifer porosity of 25 percent, and on estimated horizontal hydraulic conductivity values obtained from slug testing shallow groundwater monitoring wells. The wide range of groundwater velocity estimates is expected in a complex fluvial depositional environment.

Groundwater flow velocity estimates can be used to help assess the distance that a constituent may migrate from a potential source area, and to help estimate the groundwater flux through a portion of an aquifer. On the basis of the range of area-specific horizontal hydraulic gradients presented in Section 5.1.1, an assumed aquifer porosity of 25 percent, and the shallow horizontal hydraulic conductivity estimates described in Section 5.2.1, shallow groundwater velocity ranges were estimated for the following areas at the site:

- North of the RMC facility
- East of the RMC facility
- South of the South Ditch
- Beneath the RMC plant

The estimated groundwater velocity for each area was calculated using the following equation:

$$v = (KI)/n$$

where:

v = groundwater velocity (ft/day)
K = horizontal hydraulic conductivity (ft/day)
I = horizontal hydraulic gradient (ft/ft)
n = estimated shallow aquifer porosity (dimensionless)

5.3.1 North of the RMC Facility

The range of estimated horizontal hydraulic gradients for the shallow aquifer north of the RMC facility is 0.002 to 0.003 ft/ft. The range of horizontal hydraulic conductivity estimates obtained from slug testing shallow wells north of the dike is 30 ft/day

(0.01 cm/sec) at MW21-12 to 100 ft/day (0.03 cm/sec) at MW09. The hydraulic conductivity estimate at MW21-25 [9.5 ft/day (0.003.5 cm/sec)] was not used because it is believed to be unreasonably low given the sediment type (medium- to coarse-grained sand) in which MW21-25 is screened. Therefore, on the basis of available data, the range of estimated shallow groundwater flow velocities north of the dike is 0.24 to 1.2 ft/day (0.073 to 0.366 m/day).

5.3.2 East of the RMC Facility

The range of estimated horizontal hydraulic gradients for the shallow aquifer east of the RMC facility is 0.01 to 0.02 ft/ft. The range of horizontal hydraulic conductivity estimates obtained from slug testing shallow wells east of the facility is 0.04 ft/day ($1.4x10^{5}$ cm/sec) at MW25-35 to 2.88 ft/day (0.001 cm/sec) at MW10. Therefore, on the basis of available data, the range of estimated shallow groundwater flow velocities east of the facility is 0.002 to 0.23 ft/day (0.0006 to 0.07 m/day).

5.3.3 South of the South Ditch

The estimated horizontal hydraulic gradient for the shallow aquifer south of the South Ditch is 0.003 ft/ft. The range of horizontal hydraulic conductivity estimates obtained from slug testing shallow wells south of the South Ditch is 0.45 ft/day (0.0002 cm/sec) at MW18-31 to 5.33 ft/day (0.0019 cm/sec) at MW17-16. Therefore, on the basis of available data, the range of estimated shallow groundwater flow velocities south of the South Ditch is 0.005 to 0.06 ft/day (0.0015 to 0.0183 m/day).

5.3.4 Beneath the RMC Plant

The estimated horizontal hydraulic gradient for the shallow aquifer beneath the RMC plant is 0.002 ft/ft. The range of horizontal hydraulic conductivity estimates obtained from slug testing shallow wells nearest the plant is 0.06 ft/day ($2.12x10^{-5}$ cm/sec) at MW04 to 20 ft/day (0.0071 cm/sec) at MW01. Therefore, on the basis of available data, a possible range of estimated shallow groundwater flow velocities beneath the plant is 0.001 to 0.16 ft/day (0.0003 to 0.0488 m/day).

SECTION 6

WATER QUALITY

Section 6
Water Quality

Groundwater samples from shallow monitoring wells and selected production wells were analyzed for major cations and anions to help evaluate shallow-to-deep aquifer mixing, and any additional chemical patterns or characteristics that could aid in development of the conceptual hydrogeologic model. Major ion concentration ratios can be indicative of specific characteristics of groundwater flowing through rock or aquifer material of different types or ages, or material that is exposed to manmade sources of dissolved constituents. Comparison of major ion ratios and concentrations among sampling locations can provide insight into the possible relationships among groundwater flow systems at the site, and the distribution of chemical constituents in groundwater.

Ten shallow groundwater monitoring wells, three deeper groundwater production wells, and one offsite former irrigation well were sampled during the second quarterly monitoring event in February 1995. Nineteen additional monitoring wells were analyzed for general chemical constituents in August and September 1995. The groundwater monitoring well locations are shown in Figure 6-1. Sampling methods and quality control samples were described in CH2M HILL, 1995c, and CH2M HILL, 1995e. Well construction information, including total well depths, screened interval elevations, and aquifer type for each well presented in this section, is summarized in Table 6-1. Field parameter measurements (pH, temperature, and electrical conductivity) are presented in CH2M HILL, 1995e.

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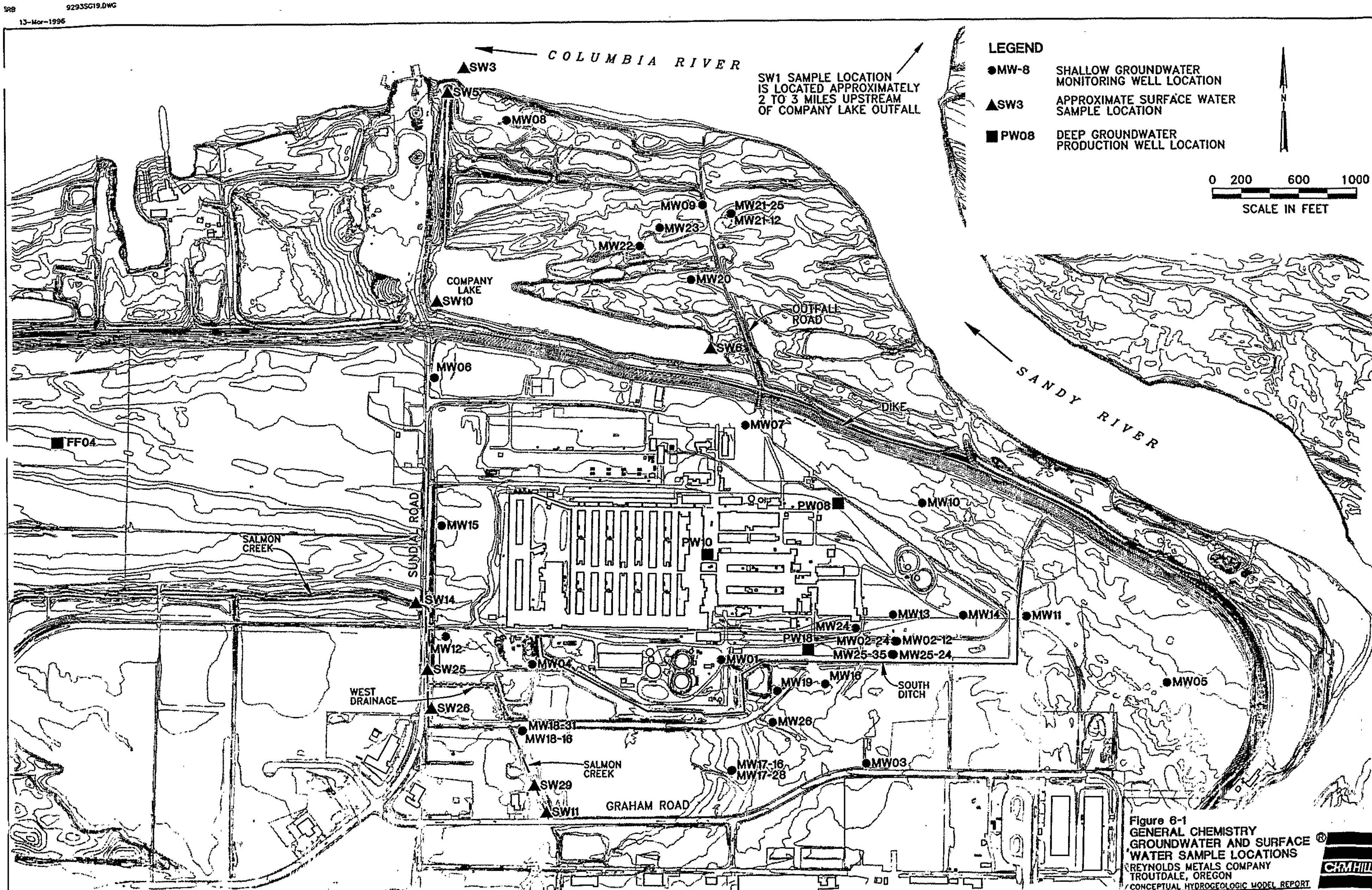


Figure 6-1
GENERAL CHEMISTRY GROUNDWATER AND SURFACE WATER SAMPLE LOCATIONS
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
CONCEPTUAL HYDROGEOLOGIC MODEL REPORT

9293SG19.DWG

Table 6-1
Well Construction Data Summary
Reynolds Metals Company
Troutdale, Oregon

Well ID	Total Depth (ft bgs) (a)	Screened Interval Elevations (ft, NGVD) (b)	Aquifer Zone	Aquifer Type
MW01	20	6.2 to 16.2	Shallow	Appears to be USA
MW02-12 (formerly TMW05)	12.5	16.3 to 21.3	Shallow	USA
MW02-24 (formerly MW02)	24	4.6 to 14.6	Shallow	USA
MW03	18	10.4 to 18.4	Shallow	USA
MW04	20	5.3 to 15.3	Shallow	USA
MW06	25	0.6 to 10.6	Shallow	USA
MW07	25	4.7 to 14.7	Shallow	USA
MW08	28	(-) 4.2 to 5.8	Shallow	USA
MW09	32	(-) 3 to 7	Shallow	USA
MW10	25	4.9 to 19.9	Shallow	USA
MW11	19	12.5 to 22.5	Shallow	USA
MW12	23	(-) 0.8 to 4.2	Shallow	USA
MW13	23	6.3 to 11.3	Shallow	USA
MW14	16	13.3 to 23.3	Shallow	USA
MW15	25	(-) 2.8 to 7.3	Shallow	USA
MW16	14	13.2 to 21.2	Shallow	USA
MW17-16	17	8.8 to 13.8	Shallow	USA
MW17-28	28.5	(-) 3.2 to 1.8	Shallow	USA
MW18-16	16.5	5.5 to 10.5	Shallow	USA
MW18-31	32	(-) 10 to (-) 5	Shallow	USA
MW19	13.5	11.8 to 16.8	Shallow	USA
MW20	26.5	(-) 0.2 to 9.8	Shallow	USA
MW21-12 (formerly TMW07)	12	10.9 to 15.4	Shallow	USA
MW21-25 (formerly MW21)	25	(-) 1.5 to 3	Shallow	USA
MW22	27	(-) 3.9 to 5.6	Shallow	USA
MW23 (formerly TMW06)	25	(-) 04 to 9.1	Shallow	USA
MW24 (formerly TMW01)	12.5	17.3 to 22.3	Shallow	USA
MW25-24 (formerly TMW02)	24	5.5 to 15.5	Shallow	USA
MW25-35 (formerly TMW04)	35.5	(-) 6.6 to (-) 1.6	Shallow	USA
MW26 (formerly TMW03)	12.5	11.9 to 16.9	Shallow	USA
PW08	248	-131 to -215	Deep	
PW10	625	-116 to -157	Deep	Appears to be lower SGA
PW18	300	-120 to -232	Deep	Lower USA
Fairview Farms No. 4	200	-96 to -177	Deep	

Notes:

(a) ft bgs = feet below ground surface

(b) ft NGVD = feet referenced to National Geodetic Vertical Datum, 1929.

Screened interval elevations calculated from: Ground surface elevations (ft NGVD) - Screened interval (ft bgs).

Production well (PW-) screened interval elevations were estimated by assuming ground surface is 3 feet below measure point.

To evaluate general water chemistry, groundwater samples were analyzed for total dissolved solids (TDS) and major ions listed in Table 6-2.

Table 6-2
Summary of General Chemistry Major Ions

Major Ions Analyzed	
Cations	**Anions**
Calcium (Ca)	Bicarbonate (HCO_3)
Magnesium (Mg)	Carbonate (CO_3)
Sodium (Na)	Sulfate (SO_4)
Potassium (K)	Chloride (Cl)
Iron (Fe)	Nitrate (NO_3) as total Nitrogen
	Fluoride (F)
	Cyanide (CN)

General chemistry analytical results are summarized in Table 6-3. The cation/anion ratio is calculated by dividing the total number of positive (+) milliequivalents per liter by the total number of negative (-) milliequivalents per liter. Milliequivalents per liter (meq/L) is the ion concentration in terms of electrical charge (valence), and it is calculated from concentration data. Theoretically, solutions in chemical equilibrium are neutral in charge and have a cation/anion ratio of 1.0. Cation/anion ratios that vary from 1.0 typically result either from analytical error, because other ions are present in solution but were not analyzed, or when cation/anion sources exist in nonequilibrium concentrations.

Stiff (1951) diagrams and Piper (1944) trilinear diagrams are a method of presenting major ion concentrations (in meq/L) graphically, so samples can be more easily compared and evaluated. Stiff diagrams depict total ionic content (width) in a fixed sequence of connected lines to develop a shape that represents the water type. Piper diagrams present water type by plotting a sample within several axes so that water type is represented by location. Stiff diagrams are presented in Appendix D and Piper trilinear diagrams are shown in the text discussion.

The general chemistry composition of tested wells is presented in Appendix D. To simplify the discussion that follows in this section, samples that are considered representative of the following water types are compared:

- Relatively unaffected groundwater. This is groundwater from wells that are considered to have had little, if any, effect from past practices at the site.
- Affected groundwater. This is groundwater from wells that clearly show water quality effects from past practices at the site.

Table 6-3

Groundwater General Chemistry Data Summary

Reynolds Metals Company

Troutdale, Oregon

	Station ID	MW01	MW02-12 (formerly TMW05)	MW02-24 (formerly MW02)	MW03	MW04	MW06	MW08	MW09	MW10	MW11	MW12	MW13	MW14	MW15	MW16	MW17-16	MW17-28	MW18-16
	Date Sampled:	2/6/95	8/7/95	2/7/95	2/7/95	2/6/95	2/7/95	2/7/95	2/7/95	2/6/95	2/6/95	2/7/95	8/7/95	8/7/95	8/8/95	8/9/95	8/8/95	8/9/95	8/8/95
Analyte	**Units**																		
Alkalinity, Bicarbonate	mg/L	68	83.3	72	43	1100	75	120	120	64	340	200	168	25.6	87.2	36.8	79.8	80.1	78.8
Alkalinity, Carbonate	mg/L	10 U	1 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	20	10 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
Alkalinity, Total as CaCO3	mg/L		83.3										168	25.6	87.2	36.8	79.8	80.1	78.8
Chloride	mg/L	18	3.5	3	2.5	32	2.2	24	35	5.5	2.5 U	6.5	6.8	.4	10.7	15	5	2.4	6.6
Hardness (a)	mg CaCO3	25.22	80.56	47.54	31.93	58.07	51.08	59.64	33.95	57.97	156.53	64.14	13.46	17.53	89.50	26.72	70.48	59.60	87.62
Nitrate-N	mg/L	.79	1.4	.1 U	1.8	.1 U	1	.47	.1 U	.12	2.9	.1 U	4.9	.7	.1 U	2.3	.1 U	.3	.1 U
Sulfate	mg/L	18	19	18	10	12	2.2	23	34	4.4	22	48	38	3.4	6.9	6.5	13	17	110 D
TDS	mg/L	220	370	220	130	2000	140	240	320	150	1800	390	590	70	190	140	270	160	320
Fluoride (Total)	mg/L	28	18	23	0.5 U	93	0.5 U	6.8	13	0.5 U	490	0.5 U	100	6.8	0.5 L	8	0.4	0.6	4.4
Field pH	[H⁺]	6.65	6.68	6.28	5.85	6.72	6.04	6.22	6.22	5.83	8.35	6.34	7.39	6.07	6.82	6.19	6.32	6.82	6.25
Total Metals																			
Aluminum	mg/L		48.5										7.58	2.59	.576	1.85	7.1	.151	1.21
Iron	mg/L	.22	26.8	11	4.9	17	.1 U	.2	.1 U	5	77	12	5.96	.656	.643	.1 U	9.68	15.1	13.7
Lead	mg/L	.004 U	.021	.004 U	.004 U	.025	.004 U	.004 U	.004 U	.0041	.03	.004 U	.005 U	.005 U	.005 U	.005 U	.005 U	.005 U	.005 U
Magnesium	mg/L	.85	7.86	7.3	2.6	4.4	6.4	6.6	4	6.8	18	8.3	1.45	1.45	9.91	1.96	8.08	8.41	10
Manganese	mg/L		.588										.0699	.226	.874	.02 U	.696	.835	1.41
Mercury	mg/L	.0005 U	.00033	.0005 U	.0005 U	.0005 U	.0005 U	.0005 U	.0005 U	.0005 U	.0007	.0005 U	.0002 U	.0002 U	.0002 U	.0002 U	.0002 U	.0002 U	.0002 U
Nickel	mg/L	.05 U	.04 U	.05 U	.05 U	.05 U	.05 U	.05 U	.05 U	.05 U	.14	.05 U	.04 U	.04 U	.04 U	.04 U	.04 U	.04 U	.04 U
Potassium	mg/L	2.2	5.94	2.6	3.8	5.4	1.8	2.6	2.4	2.2	12	1.6	2.49	2.13	1.5	5.68	2.91	1	2.36
Silver	mg/L	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U
Sodium	mg/L	69	68	34	6.5	620	5.8	56	86	16	720	90	208	10.5	12.3	25.2	15.2	16.2	51.2
Thallium	mg/L	.004 U	.002 U	.004 U	.004 U	.004 U	.004 U	.004 U	.004 U	.004 U	.004 U	.004 U	.002 U	.002 U	.002 U	.002 U	.002 U	.002 U	.002 U
Antimony	mg/L	.005 UL	.005 U	.005 UL	.005 UL	.005 UL	.005 UL	.005 UL	.005 UL	.005 UL	.005 UL	.005 UL	.005 U	.005 U	.005 U	.005 U	.005 U	.005 U	.005 U
Arsenic	mg/L	.004 U	.00509	.004 U	.004 U	.017	.004 U	.004 U	.004 U	.004 U	.16	.004 U	.0111	.004 U	.004 U	.004 U	.004 U	.004 U	.004 U
Barium	mg/L		.387										.0636	.02 U	.0366	.02 U	.104	.0332	.103
Beryllium	mg/L	.02 U	.005	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.0039	.00041	.0003 U	.00061	.00033	.0003 U	.001
Cadmium	mg/L	.0003 U	.004 U	.0003 U	.0003 U	.0007	.0003 U	.0003 U	.0003 U	.0003 U	.0018	.0003 U	.004 U	.004 U	.004 U	.004 U	.004 U	.004 U	.004 U
Chromium	mg/L	.02 U	.02 U	.02 U	.02 U	0.87	.02 U	.024	.02 U	.02 U	.062	.02 U	.0262	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U
Cobalt	mg/L		.05 U										.05 U	.05 U	.05 U	.05 U	.05 U	.05 U	.05 U
Copper	mg/L	.02 U	.0384	.02 U	.02 U	.062	.02 U	.02 U	.02 U	.02 U	.32	.02 U	.0411	.0103	.005 U	.008	.0134	.005 U	.005 U
Vanadium	mg/L		.0521										.067	.02 U	.02 U	.02 U	.02	.02 U	.02 U
Zinc	mg/L	.05 U	.0949	.05 U	.05 U	.054	.05 U	.05 U	.05 U	.05 U	.16	.05 U	.05 U	.05 U	.05 U	.05 U	.05 U	.05 U	.05 U
Calcium	mg/L	8.7	19.3	7	8.5	16	9.9	13	7	12	33	12	3	4.63	19.5	7.47	14.9	10	18.6
Selenium	mg/L	.004 UL	.005 U	.004 UL	.004 UL	.013 L	.004 UL	.004 UL	.004 UL	.004 UL	.032 L	.004 UL	.005 U	.005 U	.005 U	.005 U	.005 U	.005 U	.005 U

Notes:

(a) **Hardness** (mg equivalent CaCO3/L) calculated by: 2.497 (Ca, mg/L) + 4.118 (Mg, mg/L)

Qualifiers:

U = Not detected at posted value.

B = Value estimated low.

D = Dilution.

L = Value estimated low.

Table 6-3
Groundwater General Chemistry Data Summary
Reynolds Metals Company
Troutdale, Oregon

	Station ID	MW18-31	MW19	MW20	MW21-12 (formerly TMW07)	MW21-25 (formerly MW21)	MW22	MW23 (formerly TMW06)	MW24 (formerly TMW01)	MW25-24 (formerly TMW02)	MW25-35 (formerly TMW04)	MW26 (formerly TMW03)	FF04	PW08	PW10	PW18
	Date Sampled:	8/9/95	8/9/95	9/11/95	9/11/95	9/11/95	9/11/95	9/11/95	8/8/95	8/8/95	8/8/95	8/9/95	2/8/95	2/8/95	2/8/95	2/8/95
Analyte	**Units**															
Alkalinity, Bicarbonate	mg/L	175	184	82.9	570	245	91.2	165	27	8.5	68.7	342	110	120	110	62
Alkalinity, Carbonate	mg/L	1 U	1 U	1 U	1	1 U	1 U	1 U	1 U	1 U	1 U	1 U	10 U	10 U	10 U	10 U
Alkalinity, Total as CaCO3	mg/L	175	184	82.9	570	245	91.2	165	27	8.5	68.7	342				
Chloride	mg/L	19 D	4.1	12	.1	9 D	36 D	17	1.9	3.7	2.2	6.8	2.2	7	200	2
Hardness (a)	mg CaCO3	170.18	11.16	86.85	128.68	113.12	80.73	98.10	22.04	22.08	48.75	12.25	94.08	94.13	242.77	45.61
Nitrate-N	mg/L	.1 U	.9	.3	.1	2	.3	1.3	2.6	1.6	.1 U	2.2	.1 U	.1 U	.1 U	.1 U
Sulfate	mg/L	27	45	15	1	48	20	69 D	19	10	3.7	51	1 U	4.1	6	1 U
TDS	mg/L	280	480	190	790	430	250	410	150	150	160	580	170	200	630	110
Fluoride (Total)	mg/L	0.85	69	6.3 L	34 L	11 L	12 L	19 L	14 L	18	0.55 L	72 L	0.5 U	1.5	1	0.61
Field pH	[H+]	6.75	6.84	6.33	6.38	6.14	6.25	6.29	6.07	6.60	6.73	7.21	6.82	7.56	8.09	7.75
Total Metals																
Aluminum	mg/L	.297	10.5	.308	11.7	1.92	1.3	2.58	2.59	9.63	.1 U	9.92				
Iron	mg/L	4.22	2.15	.1 U	128	.1 U	.1 U	.1 U	.33	4.34	5.45	3.44	1.9	2	.15	2.2
Lead	mg/L	.005 U	.005 U	.005 U	.005	.005 U	.005 U	.005 U	.005 U	.005 U	.005 U	.005 U	.004 U	.004 U	.004 U	.004 U
Magnesium	mg/L	17.8	1.11	3.99	13.3	13.1	4.87	10.3	1.63	2.47	5.35	1.27	8.9	7.7	6.2	3.8
Manganese	mg/L	4.12	.146	.02 U	2.14	.02 U	.188	.0273	.0906	.115	1.09	.108				
Mercury	mg/L	.0002 U	.00022	.0002 U	.0002 U	.0002 U	.0002 U	.0002 U	.0002 U	.0002 U	.0002 U	.0002 U	.0005 U	.0005 U	.0005 U	.0005 U
Nickel	mg/L	.04 U	.04 U	.04 U	.04 U	.04 U	.04 U	.04 U	.04 U	.04 U	.04 U	.04 U	.05 U	.05 U	.05 U	.05 U
Potassium	mg/L	3.28	5.87	2.95	7.09	2.77	2.95	2.2	2.69	1.7	2.09	6.28	3.2	3.6	7.8	3
Silver	mg/L	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U
Sodium	mg/L	22.1	171	22.2	230 D	108	48.8	105	17.9	22.4	10	266 D	8.5	15	94	7.8
Thallium	mg/L	.002 U	.002 U	.002 U	.002 U	.002 U	.002 U	.002 U	.002 U	.002 U	.002 U	.002 U	.004 U	.004 U	.004 U	.004 U
Antimony	mg/L	.005 U	.005 U	.005 U	.005 U	.005 U	.005 U	.005 U	.005 U	.005 U	.005 U	.005 U	.005 UL	.005 UL	.005 UL	.005 UL
Arsenic	mg/L	.004 U	.004 U	.004 U	.004 U	.004 U	.004 U	.004 U	.004 U	.004 U	.004 U	.004 U	.004 U	.004 U	.004 U	.004 U
Barium	mg/L	.08309	.02 U	.0307	.07779	.0585	.0677	.0506	.033	.0568	.0249	.0375				
Beryllium	mg/L	.0003 U	.0043	.00061	.0147	.002	.0011	.0029	.0004	.0028	.0003 U	.0024	.02 U	.02 U	.02 U	.02 U
Cadmium	mg/L	.004 U	.004 U	.004 U	.004 U	.004 U	.004 U	.004 U	.004 U	.004 U	.004 U	.004 U	.0003 U	.0003 U	.0003 U	.0003 U
Chromium	mg/L	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U
Cobalt	mg/L	.05 U	.05 U	.05 U	.05 U	.05 U	.05 U	.05 U	.05 U	.05 U	.05 U	.05 U				
Copper	mg/L	.005 U	.0438	.005 U	.0061	.005 U	.005 U	.005 U	.005 U	.0058	.005 U	.0583	.02 U	.02 U	.02 U	.02 U
Vanadium	mg/L	.02 U	.0343	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.0909				
Zinc	mg/L	.05 U	.05 U	.05 U	.05 U	.05 U	.05 U	.05 U	.05 U	.05 U	.05 U	.05 U	.05 U	.05 U	.05 U	.05 U
Calcium	mg/L	38.8	2.64	28.2	29.6	23.7	24.3	22.3	6.14	4.77	10.7	2.81	23	25	87	12
Selenium	mg/L	.005 U	.005 U	.005 U	.005 U	.005 U	.005 U	.005 U	.005 U	.005 U	.005 U	.005 U	.004 UL	.004 UL	.004 UL	.004 UL

Notes:

(a) Hardness (mg equivalent CaCO3/L) calculated by: 2.497 (Ca, mg/L) + 4.118 (Mg, mg/L)

Qualifiers: U = Not detected at posted value.

B = Value estimated low.

D = Dilution.

L = Value estimated low.

- Deep groundwater
- Surface water

6.1 Shallow Groundwater

In general, relatively unaffected shallow groundwater is defined as water samples that contain sodium + potassium concentrations ranging from less than 1.0 to 4 meq/L and bicarbonate concentrations ranging from less than 1.0 to 3.5 meq/L. Relatively unaffected well locations include: MW01, MW02-12, MW02-24, MW03, MW06, MW08, MW09, MW10, MW12, MW14, MW15, MW16, MW17-16, MW17-28, MW18-16, MW18-31, MW20, MW22, MW24, MW25-24, and MW25-35.

Affected shallow groundwater is defined as containing elevated concentrations of sodium + potassium (from 5 to 27 meq/L) and bicarbonate (from 3 to 19 meq/L). Affected well locations include: MW04, MW11, MW13, MW19, MW21-12, MW21-25, MW23, and MW26.

Selected samples representative of unaffected shallow groundwater (from MW03, MW06, MW10, and MW20) are plotted in the Piper diagram shown in Figure 6-2. This plot shows that groundwater unaffected by site activities exhibits generally similar constituent ratios and concentrations, at locations both upgradient and downgradient of the main plant area.

Selected samples representative of shallow groundwater that appears to have been affected by site activities (from MW04, MW11, MW21-12, and MW26) are plotted in the Piper diagram shown in Figure 6-3. These water samples are distinctly different from groundwater samples shown in Figure 6-2, primarily because they contain higher TDS and higher proportions of sodium, bicarbonate, and fluoride. Despite their various locations across the site, the affected wells exhibit water quality that is fairly similar regardless of the source area with which each well is associated—suggesting that the effect of different contaminant source areas at the site on major ion distribution in groundwater is similar. Each of the affected shallow groundwater samples was of the sodium-bicarbonate type, defined as containing at least 50 percent sodium and bicarbonate of total meq/L.

6.2 Deep Groundwater

Figure 6-4 shows a Piper diagram depicting the general chemistry of samples collected from well locations FF04, PW08, PW10, and PW18. Groundwater samples from FF04, PW08, and PW18 appear similar, contain low TDS, and bicarbonate predominates. Groundwater at PW10 is distinct from the other three deep wells, contains somewhat elevated TDS, and chloride predominates. The difference between PW10 and the other sampled deep well water chemistry is likely the result of the screened interval at PW10, which is much deeper

107493.D4.01 Reynolds Metals Co. 11/95

#	Date YYMMDD	Well I.D.
1	020795	MW03
2	020795	MW06
3	020695	MW10
4	091195	MW20

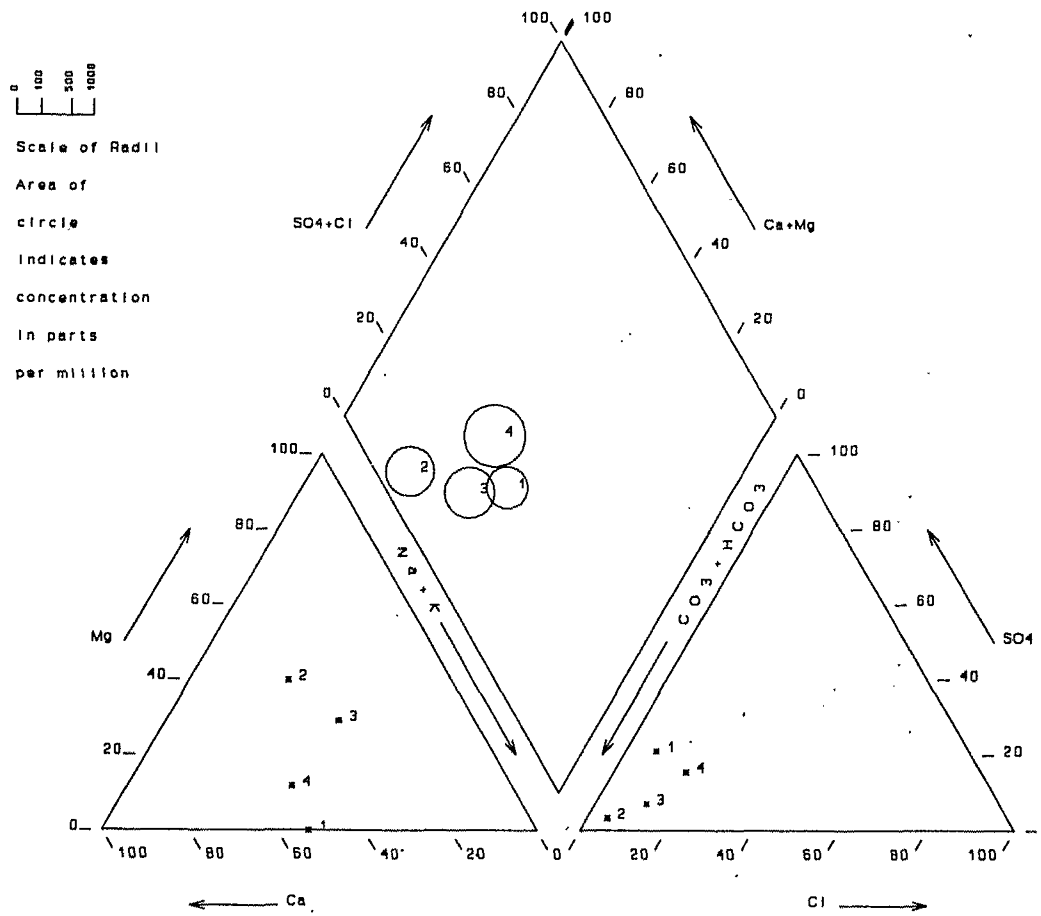


Figure 6-2
PIPER DIAGRAM SHOWING REPRESENTATIVE UNAFFECTED SHALLOW GROUNDWATER
REYNOLDS METALS COMPANY
TROUTDALE, OREGON

CH2M HILL

#	Date YYMMDD	Well I D
1	020695	MW04
2	020695	MW11
3	091195	MW21-12
4	080995	MW26

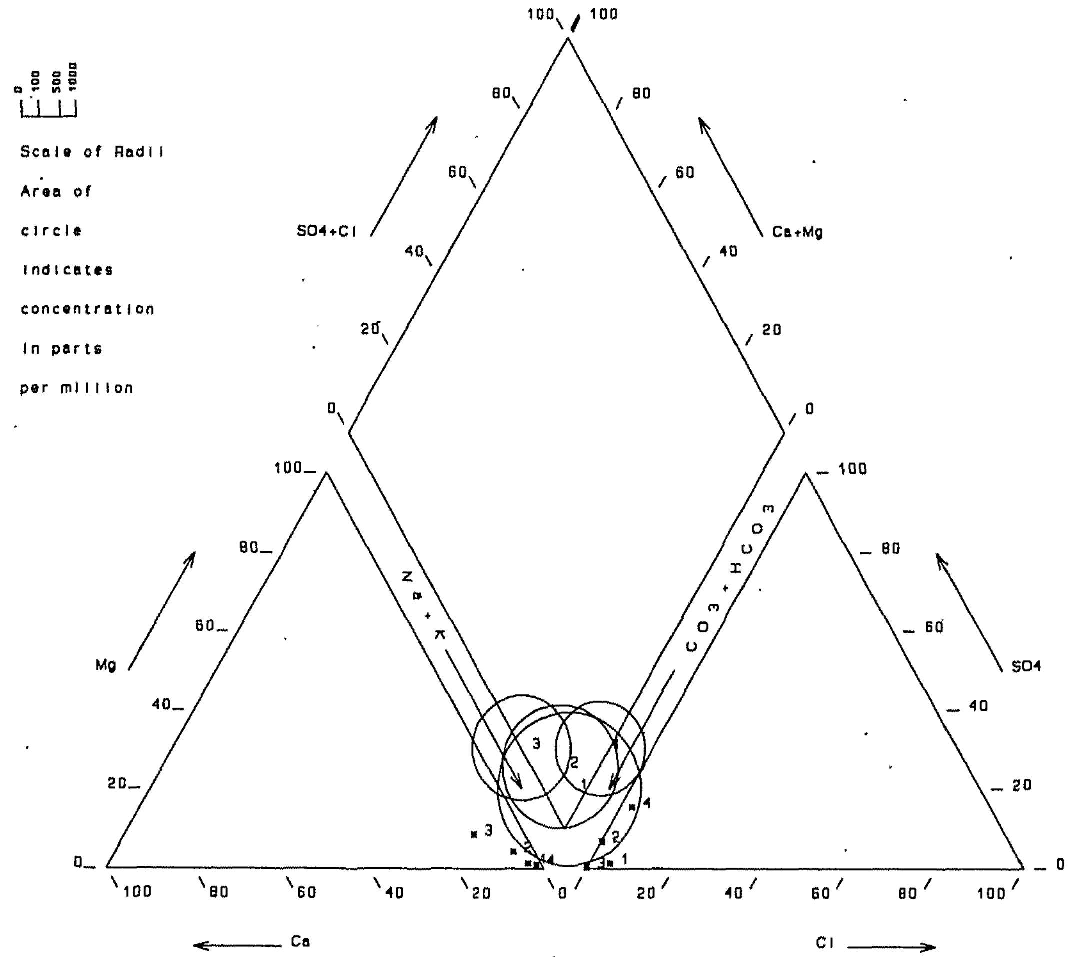
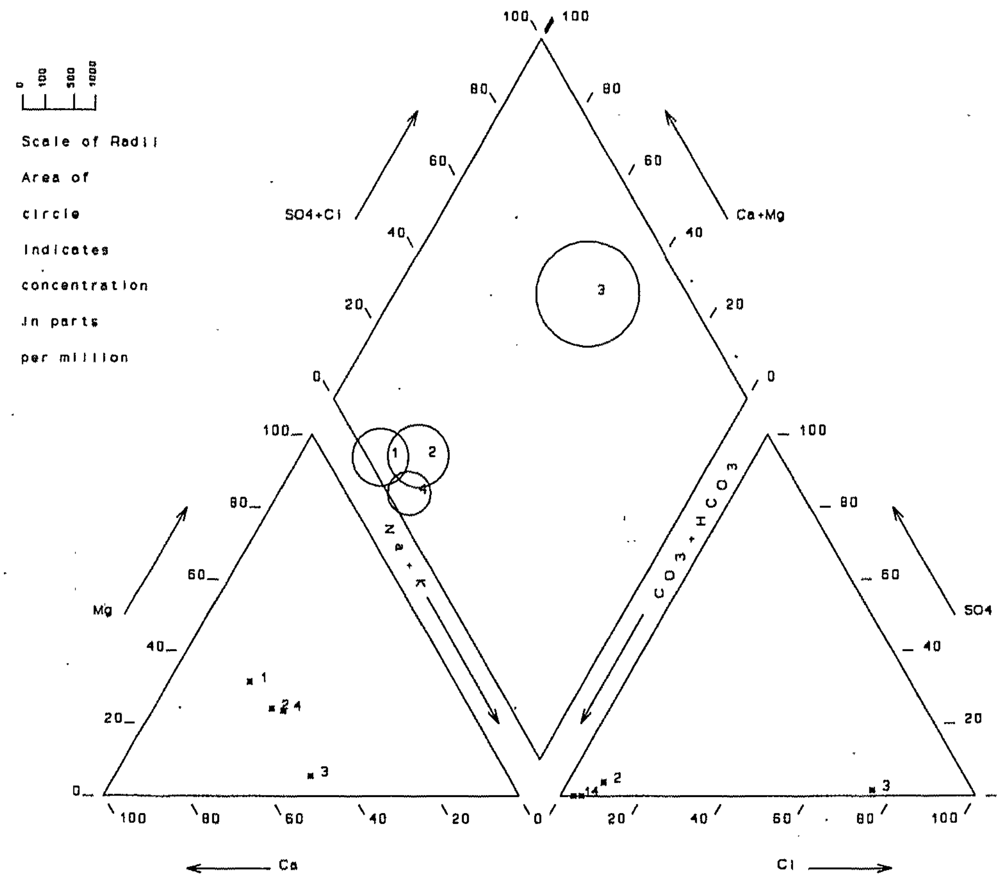


Figure 6-3
PIPER DIAGRAM SHOWING
REPRESENTATIVE AFFECTED
SHALLOW GROUNDWATER
REYNOLDS METALS COMPANY
TROUTDALE, OREGON

CH2M HILL

107493.D4.01 Reynolds Metals Co. 11/95



#	Date YYMMDD	Well I.D.
1	020895	FF04
2	020895	PW08
3	020895	PW10
4	020895	PW18

Figure 6-4
PIPER DIAGRAM SHOWING REPRESENTATIVE DEEP GROUNDWATER GENERAL CHEMISTRY
REYNOLDS METALS COMPANY
TROUTDALE, OREGON

CH2M HILL

than the screened interval of the other deep wells sampled. Cross section A-A′ (see Figure 3-4) indicates that PW10 is screened in the lower portion of the SGA, while the other sampled wells are screened primarily in shallower USA sediments. An increase in chloride salinity with depth is a well-documented phenomenon in the Portland area; it is caused by saline water associated with deeper marine sedimentary rocks (Swanson et al., 1993).

6.3 A Comparison of Deep and Shallow Groundwater General Chemistry

Selected samples representative of affected shallow groundwater (MW11), unaffected shallow groundwater (MW10), and deep groundwater (PW08) are plotted in the Piper diagram shown in Figure 6-5. These data indicate that unaffected shallow groundwater and deep groundwater are similar in overall composition. Unaffected shallow groundwater, collected from screened intervals between -3 feet and 26 feet elevation, contains slightly more TDS than most deep groundwater, collected from screened intervals between -232 feet and -96 feet elevation. Shallow affected groundwater is characterized by significantly higher concentrations of sodium, bicarbonate, and fluoride than deep groundwater.

6.4 Surface Water Chemistry

Surface water samples were collected in August 1994 and February 1995 from the Columbia River (SW01 and SW03), Company Lake (SW05, SW06, and SW10), and Salmon Creek (SW11, SW14, SW25, SW26, and SW29) (see Figure 6-1). Table 6-4 is a summary of the cation general chemistry data. Surface water samples were not analyzed for major anions.

Figure 6-6 shows cation general chemistry concentrations for Company Lake (SW05, SW06, SW10) surface water samples compared with shallow upgradient (MW01, MW06), shallow downgradient (MW08, MW09), and deep (PW18, FF04) groundwater well locations. Because anion data are not available, only the cation portion of the trilinear diagram was plotted. In general, Company Lake surface water cation concentrations show little variability regardless of sampling location along the lake, although SW10 shows slightly higher calcium concentrations. Comparison of surface water and groundwater cation concentrations shows that the Company Lake samples are most similar to PW18.

Columbia River outfall (SW03) surface water concentrations appear slightly higher in calcium and magnesium than do the Company Lake samples. The Columbia River outfall concentrations appear similar to deep groundwater (FF04) concentrations.

Figure 6-7 shows cation general chemistry concentrations for Salmon Creek (SW11, SW14, SW26) surface water, shallow cross-gradient (MW18-16, MW12), shallow downgradient (MW15), and deep (FF04) groundwater well locations. Only cation concentrations are plotted and compared. In general, cation concentrations show little variability regardless of location along Salmon Creek. Comparison of surface water and groundwater cation concentrations shows that Salmon Creek samples from SW11, SW14, and SW26 appear most similar to deep groundwater from well FF04. In addition, SW14 and SW26 calcium

#	Date YYMMDD	Well I.D.
1	020895	PW08
2	020695	MW10
3	020695	MW11

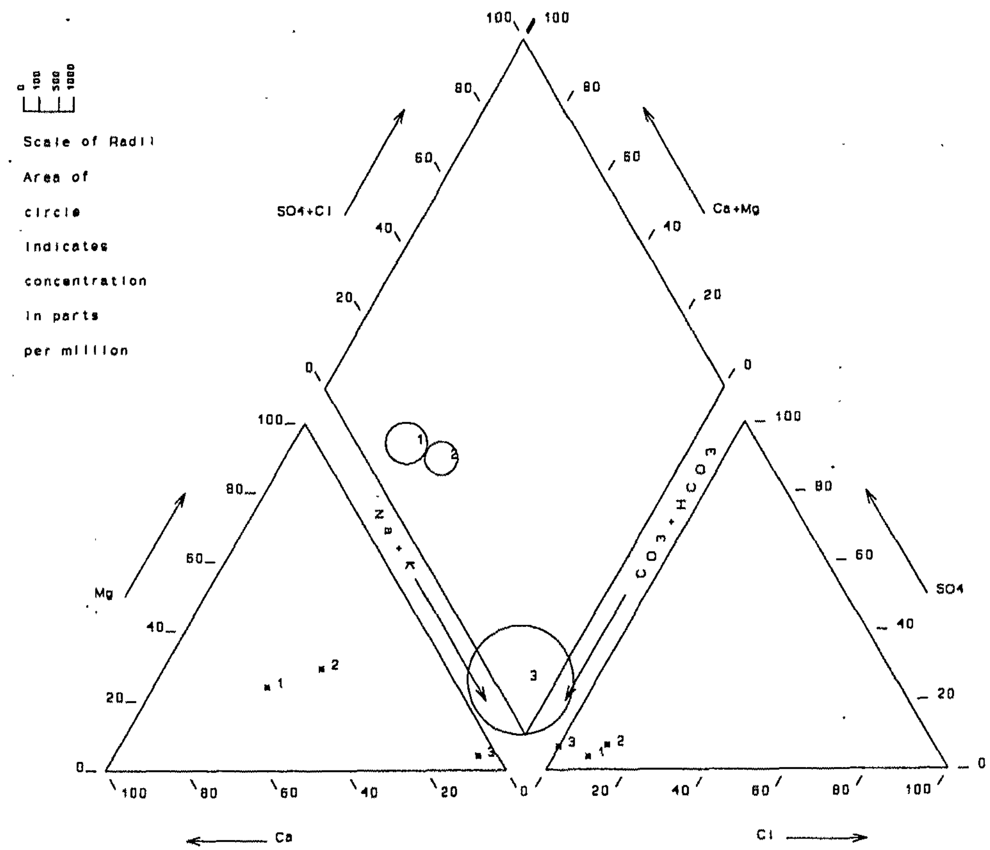


Figure 6-5
PIPER DIAGRAM SHOWING COMPARISON BETWEEN REPRESENTATIVE AFFECTED (MW11) AND UNAFFECTED (MW10) SHALLOW GROUNDWATER AND DEEP (PW08) GROUNDWATER GENERAL CHEMISTRY CONCENTRATIONS
REYNOLDS METALS COMPANY
TROUTDALE, OREGON

CH2M HILL

Table 6-4

Surface Water General Chemistry Data Summary

Reynolds Metals Company

Troutdale, Oregon

		Columbia River		Salmon Creek						Company Lake		
	Station ID	SW1	SW3	SW11	SW14	SW14D	SW25	SW26	SW29	RM-SW5	RM-SW6	RM-SW10
	Date	8/18/94	8/18/94	8/18/94	8/18/94	8/18/94	2/22/95	2/22/95	2/23/95	8/19/94	8/19/94	8/19/94
Analyte	Units											
Alkalinity, Bicarbonate	mg/L											
Alkalinity, Carbonate	mg/L											
Alkalinity, Hydroxide	mg CaCO3											
Alkalinity, Total as CaCO3	mg/L											
Bromide	mg/L											
Chloride	mg/L											
Hexavalent Chromium (VI)	mg/L											
Hardness	mg CaCO3	57	61	57	61	58	61.75	62.99	60.52	73	82	84
Nitrate-N	mg/L											
Sulfate	mg/L											
Sulfide												
TDS	mg/L											
TOC												
Fluoride (Dissolved)	mg/L	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	1.0	0.50 U	0.50 U	2.3	3	1.7
Total Metals												
Aluminum	mg/L	.1 U	.74	.1	.48	.28	.46	.14	.1 U	.6	.1 U	.1 U
Iron	mg/L	.01 U	.48	.17	.4	.27	.76	.63	.6	.34	.1 U	.3
Lead	mg/L	.004 U	.004 U	.004 U	.004 U	.004 U	.004 U	.004 U	.004 U	.004 U	.004 U	.004 U
Magnesium	mg/L	4.7	4.6	6	5.8	5.7	5.9	6.2	5.6	6.3	6	6.3
Manganese	mg/L	.02 U	.02 U	.02 U	.02 U	.02 U	.068	.058	.05	.02 U	.059	.02 U
Mercury	mg/L	.0005 U	.0005 U	.0005 U	.0005 U	.0005 U	.0005 U	.0005 U	.0005 U	.0005 U	.0005 U	.0005 U
Nickel	mg/L	.05 U	.05 U	.05 U	.05 U	.05 U	.05 U	.05 U	.05 U	.05 U	.05 U	.05 U
Potassium	mg/L	1	1 U	2.3	1.7	2.4	3.2	3.1	2.7	3.1	3.5	3.6
Silver	mg/L	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U
Sodium	mg/L	6.2	5.5	5.8	7	6.9	8.2	7.2	7.6	21	27	19
Thallium	mg/L	.004 U	.004 U	.004 U	.004 U	.004 U	.004 U	.004 U	.004 U	.004 U	.004 U	.004 U
Antimony	mg/L	.005 U	.005 U	.005 U	.005 U	.005 U	.005 U	.005 U	.005 U	.005 U	.005 U	.005 U
Arsenic	mg/L	.004 U	.004 U	.004 U	.004 U	.004 U	.004 U	.004 U	.004 U	.004 U	.004 U	.004 U
Barium	mg/L	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U
Beryllium	mg/L	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U
Cadmium	mg/L	.0003 U	.0003 U	.0003 U	.0003 U	.0003 U	.0003 U	.0003 U	.0003 U	.0003 U	.0003 U	.0003 U
Chromium	mg/L	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U
Cobalt	mg/L	.05 U	.05 U	.05 U	.05 U	.05 U	.05 U	.05 U	.05 U	.05 U	.05 U	.05 U
Copper	mg/L	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U
Vanadium	mg/L	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U	.02 U
Zinc	mg/L	.05 U	.05 U	.05 U	.05 U	.05 U	.05 U	.05 U	.05 U	.05 U	.05 U	.05 U
Calcium	mg/L	15	17	13	15	14	15	15	15	19	23	23
Selenium	mg/L	.004 U	.004 U	.004 U	.004 U	.004 U	.004 U	.004 U	.004 U	.004 U	.004 U	.004 U

Notes:

Qualifiers:

U = Not detected at posted value.
B = Value estimated low.
D = Dilution.
L = Value estimated low.

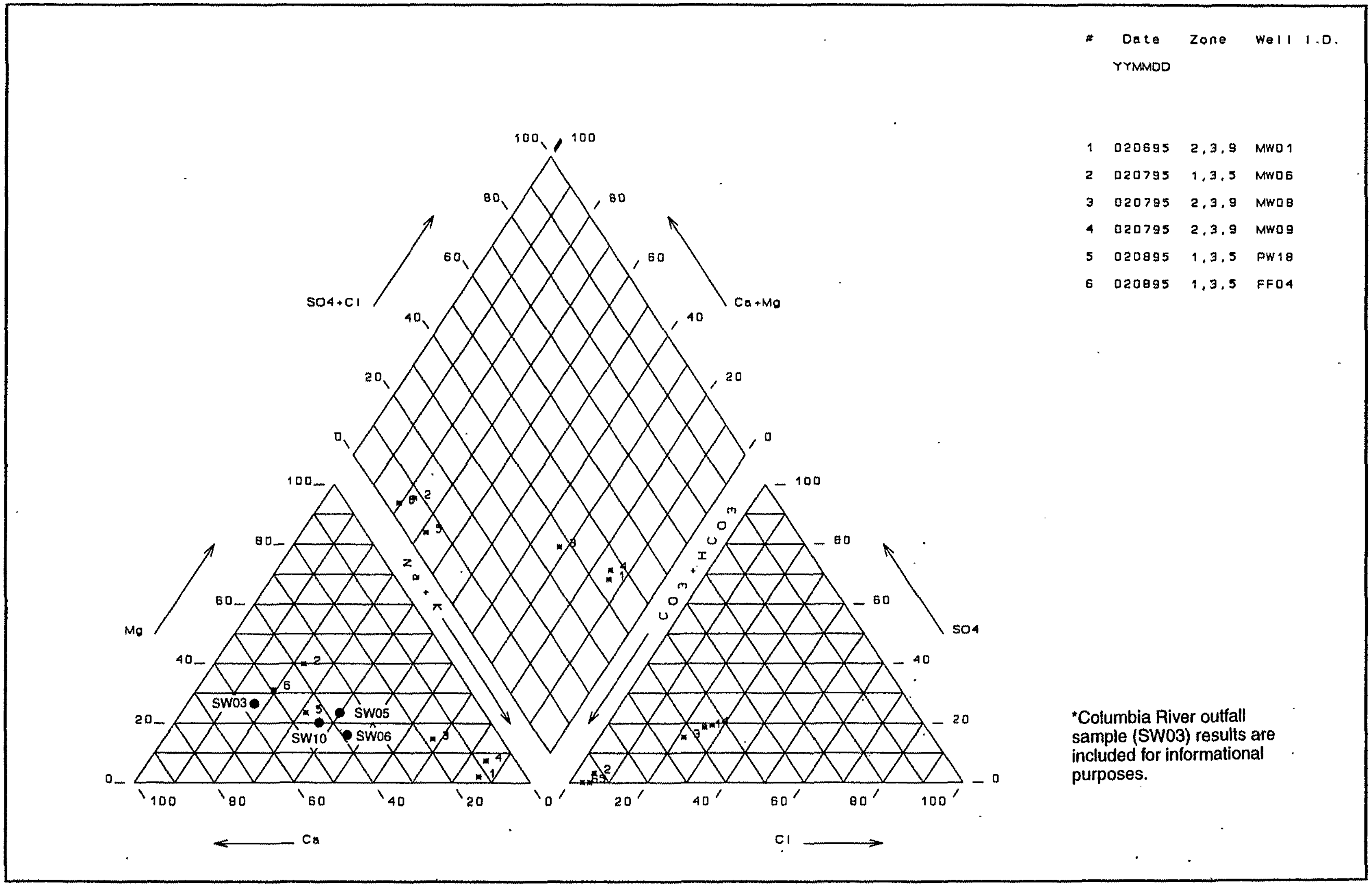


Figure 6-6
PIPER DIAGRAM COMPARING COMPANY LAKE (SW05, SW06, SW10) SURFACE WATER, SHALLOW UPGRADIENT (MW01, MW06), SHALLOW DOWNGRADIENT (MW08, MW09), AND DEEP (PW18, FF04) GROUNDWATER WELL LOCATIONS
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
CONCEPTUAL HYDROGEOLOGIC MODEL REPORT

CH2M HILL

107493.D4.08 RMC ConceptHydroModel 2.96

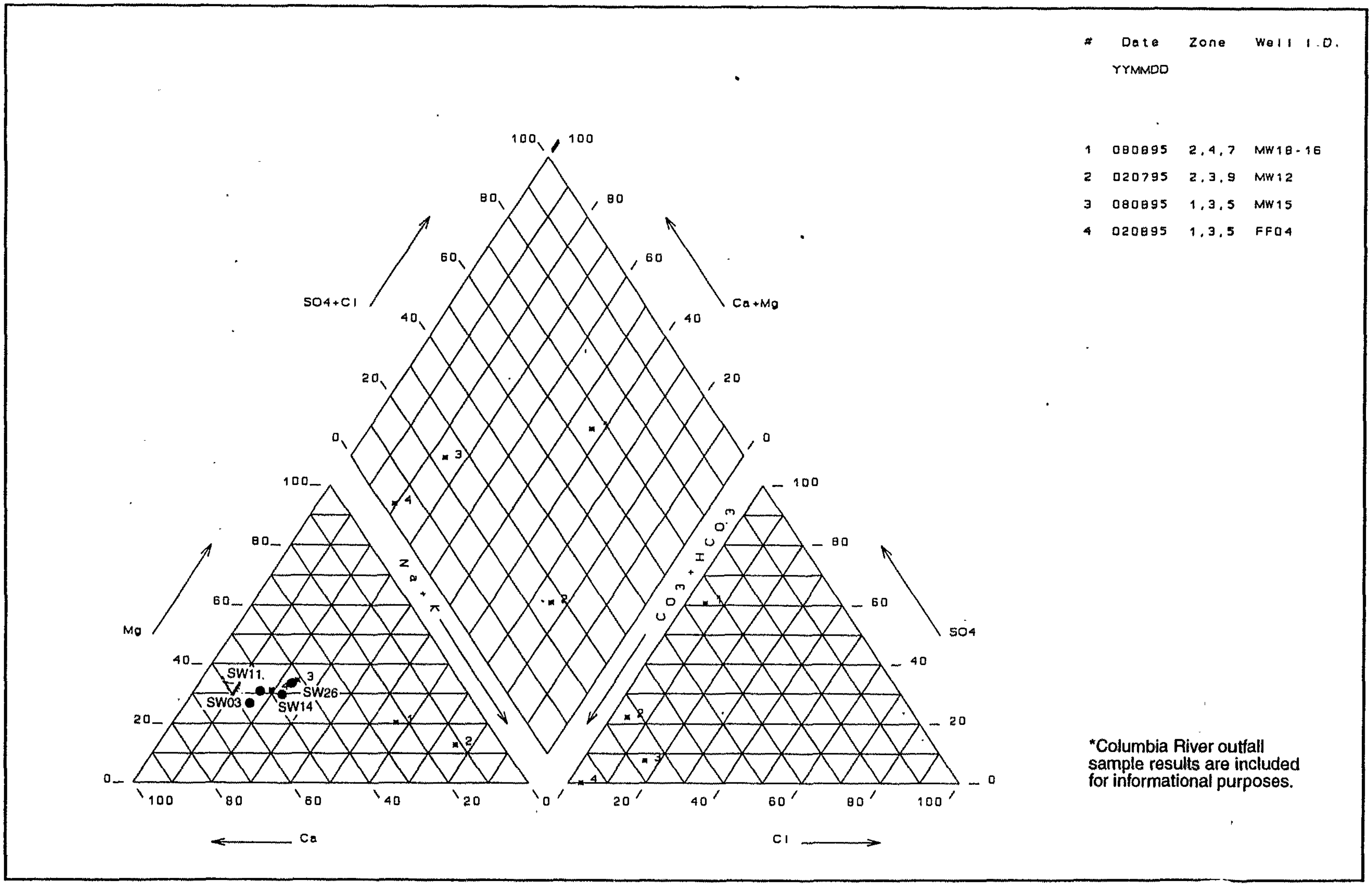


Figure 6-7
PIPER DIAGRAM COMPARING SALMON CREEK (SW11, SW14, SW26) SURFACE WATER, SHALLOW CROSS-GRADIENT (MW18-16, MW12), SHALLOW DOWNGRADIENT (MW15), AND DEEP (FF04) GROUNDWATER WELL LOCATIONS
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
CONCEPTUAL HYDROGEOLOGIC MODEL REPORT

and magnesium concentrations also appear similar to downgradient well MW15. Columbia River outfall sample (SW03) appears similar to surface water collected from Salmon Creek, although it is slightly higher in both calcium and magnesium concentrations, and lower in sodium concentration.

Water composition trends exhibited in Tables 6-3 and 6-4 show surface water cation concentrations approximately an order of magnitude less than groundwater concentration sample results. While slightly affected groundwater is characterized by water types that contain elevated sodium + potassium cation concentrations, typical surface water samples from Salmon Creek show slightly elevated calcium and magnesium cation concentrations. In addition to slightly elevated calcium and magnesium concentrations, Company Lake surface water samples contain the elevated sodium and potassium signature more typical of groundwater composition.

SECTION 7

LOCAL GROUNDWATER USE SURVEY

Section 7
Local Groundwater Use Survey

An inventory of production wells located within a one-mile radius of the site (to the south and west) was conducted using Oregon Water Resources Department (OWRD) records, as well as published and unpublished data. Areas north of the Columbia River and east of the Sandy River were excluded from this search. These surface water features appear to be local and regional discharge points for the shallow (and possibly deep) flow systems. Therefore, wells located north or east of the rivers are not likely to be potential receptors of constituents in shallow groundwater beneath the RMC site. The well data are summarized in Table 7-1. Approximate well locations are shown in Figure 7-1, and available water well driller reports are presented in Appendix E. For convenience, the tabulated water well reports are identified by well inventory numbers (WIN) in Table 7-1. The original well owner, well location information, and current well use as identified on the driller's log has been field verified for some of the local wells surrounding the site.

The well inventory search included production wells located within East Multnomah County in T1N, R3E, Sections 14, 22, 23, 24, 25, 26, and 27. A total of 38 water well reports were obtained for this area, and they include the following reported uses:

- 20 domestic wells
- 7 domestic and other uses [such as domestic and irrigation, or manufacturing (2 of these wells are owned by RMC)]
- 5 municipal wells (1 temporarily abandoned)
- 3 irrigation wells
- 2 industrial wells (1 temporarily abandoned)
- 1 test well

In addition to the reported 38 water wells in the area, RMC owns 18 production wells at the site (see Figure 1-3 and Table 7-1).

Total well depths ranged from 36 ft (WIN 28) to 1,060 ft (WIN 31), and reported groundwater yields ranged from 12 to 1,500 gpm. The majority of wells within the 1-mile radius are screened, or perforated, within materials described as water-bearing sand and gravel. These sediments most likely correspond to the Unconsolidated Sedimentary Aquifer described in Section 3. An exception is a 750-ft-deep, Port of Portland public-supply well (WIN 8) that is located approximately 300 ft south of the RMC facility, at the Troutdale Airport (Figure 7-1). This well is cased to 738 feet bgs and screened in the deeper Sand and Gravel Aquifer zone between 435 and 738 ft bgs. The pumping test yield, reported on the OWRD water well report, was 800 gpm with 58 ft of drawdown over the 24-hour pumping period. Troutdale Airport personnel indicate that the airport is currently connected to

Table 7-1
Wells Located Within 1-Mile Radius of RMC Facility
Reynolds Metals Company
Troutdale, Oregon

Well Inventory No.	Well Location (by 1/4-1/4 Section)	Original Well Owner	Date Completed	Original Well Use (a)	Total Well Depth (ft bgs) (b)	Well Yield (gpm) (c)	Static Water Level from Original Well Report (ft bgs)	Screened or Perforated Interval (ft bgs)	Water-Bearing Material & Comments
T1N R3E									
Section 14									
1	14cc	Sundial Marine Tug & Barge	Dec. 1979	D	233	60	25	228 - 233	Sand & gravel at 222' bgs. Well sampled in June 1995. See CH2M HILL 1995d.
2	14ccad	Gresham Sand & Gravel *(formerly Harris Quade)*	Nov. 1967	D	127	60	30	120 - 130	Sand, fine with gravel - med. & coarse; sand fine, gray and black. Sampled in June 1995. See CH2M HILL 1995d.
Section 22									
3	22adcc	Fairview Farms Inc. Well # 6	1950	D, I, Mn	200	1,200	17	119 - 200	Fine gray clay; Well formerly used for irrigation of 170 acres. Owned by RMC.
4	22 ?	(b) (6)	Apr. 1963	D	98' - Backfilled from 103' bgs	18	30	93 - 98	Gray sand. Well loc. = 150' No. and 50' E. of the SW corner of tax lot no. 14.
Section 23									
5	23abcd	Bonneville Power Admin. *(BPA)* Well # 1	1946	In.	183	142	10.3	NA	Gravel and Sand from 175 - 183'. Chem. analysis avail. Currently **not in use.**
6	23acaa	BPA Well # 2	Jan. 1947	In.	287	500	36	171 - 183 199 - 206 265 - 283	Sand & gravel from all 3 perforated zones. Not used for potable at substation - hand washing etc., drinking water is bottled.
7	23bcc	Fairview Farms Inc. Well # 4	1943	D, I, Mn	281	700	11	237 - 250	Sand & gravel Owned by RMC. Formerly used for irrigation.
8	23dc	Port of Portland *Troutdale Airport loc.*	June 1961	M	750	800	20	435 - 738	Sand & gravel aquifer Well currently not in use.
9	23 ?	(b) (6)	Dec. 1976	D	121	18	18	None, Cased to 113' bgs	Gray loose sand Gray sand & gravel
10	23 ?	(b) (6)	**VOID**, Well location incorrect on well log. Co. assessors office shows well in Township T1**S**, not T1**N**.						
Section 24									
11	24 ?	(b) (6)	Mar. 1964	D	170	15 - 20	25	None, Cased to 170' bgs.	Sand & gravel
Section 25									
12	25cbc	City of Troutdale Well # 4 (Shop well)	Aug. 1980	M	571	590	118	493 - 563	Sand, silt and gravel Aquifer = SGA.
13	25dc	(b) (6)	Feb. 1994	D	103	75	22	None, Cased to 99' bgs.	Sand, med. to large - multi-colored.
14	25 ?	(b) (6)	Feb. 1967	D	115	20	15	None, Cased to 115' bgs.	High iron water at 100' bgs - cased off. Coarse sand and gravel.

Table 7-1
Wells Located Within 1-Mile Radius of RMC Facility
Reynolds Metals Company
Troutdale, Oregon

Well Inventory No.	Well Location (by 1/4-1/4 Section)	Original Well Owner	Date Completed	Original Well Use (a)	Total Well Depth (ft bgs) (b)	Well Yield (gpm) (c)	Static Water Level from Original Well Report (ft bgs)	Screened or Perforated Interval (ft bgs)	Water-Bearing Material & Comments
15	25 ?	(b) (6)	Apr. 1974	T	110	20	38	105 - 110	Sandstone. Test well for restaurant.
16	25dc	(b) (6)	Feb. 1994	D	112	100	16	None, Cased to 108' bgs.	Gravel, large multi-colored w/sand - med. multicolored.
	Section 26								
17	26ccd	Board of County Commissioners	Mar. 1940	D,I	228	500	67	None, Cased to 228' bgs.	Clay and gravel.
18	26ad	(b) (6)	Jun. 1967	D	110 - Backfilled from 115' bgs.	35	25	None, Cased to 110' bgs.	Fine gravel.
19	26db	(b) (6)	Apr. 1967	D	54	35	20	None, Cased to 54' bgs.	Water bearing from 50 - 54' bgs. - loose gravel.
20	26 ?	(b) (6)	Nov. 1956	D	41	45	NA	NA	Boulders and gravel.
21	26ca	(b) (6)	Mar. 1976	D	52	12	24	None, Cased to 52' bgs.	Gravel, large.
22	26cc	Multnomah County Farm	NA	D,I	228 - Backfilled from 257' bgs.	500	65	NA	Cemented gravel - Troutdale Fm. from 195 - 228' bgs.
23	26 ?	Standard Oil Co.	Jun. 1971	D	52	36	3	31 - 47	Sandy gravel, coarse brown.
24	26 ?	(b) (6)	Jan. 1971	D	109 - Backfilled from 111' bgs.	40	70	99 - 110	Cemented gravel, some loose water-producing gravel, gray clay binder.
25	26 ?	(b) (6)	Oct. 1970	D	250	40	40	210 - 250	Blue fine sand, cemented gravel.
26	26 ?	(b) (6)	Mar. 1967	D	60	15	3	51 - 60	High silica water at 47' bgs in gravel and sand zone - cased off. Water in cemented gravel.
27	26 ?	(b) (6)	Nov. 1956	D	52	15	NA	NA	Boulders sand and gravel.
28	26 ?	Reynolds Troutdale Federal C.U.	5/1/60	D	36	40	3	None - Cased to 36' bgs.	Gravel
29	26db	(b) (6)	Jul. 1955	I	94	20	77	None - Cased to 94' bgs.	Gravel at 90 - 94' bgs. However, location uncertain.
30	26db	(b) (6)	1945	I	50	45	10	None - Cased to 50'.	GW permit No. GR2773

Table 7-1
Wells Located Within 1-Mile Radius of RMC Facility
Reynolds Metals Company
Troutdale, Oregon

Well Inventory No.	Well Location (by 1/4-1/4 Section)	Original Well Owner	Date Completed	Original Well Use (a)	Total Well Depth (ft bgs) (b)	Well Yield (gpm) (c)	Static Water Level from Original Well Report (ft bgs)	Screened or Perforated Interval (ft bgs)	Water-Bearing Material & Comments
	Section 27								
31	27cbbb	City of Fairview Well # 3	Aug. 1956	M	1,060	400	60	320 - 340	SGA aquifer - cemented gravel.
32	27c	City of Fairview New well # 6	Jul. 1992	M	314 - Backfilled from 322' bgs.	500	102	201 - 216 236 - 256 265 - 301	Well at 199 St. - TSA Aquifer. Gravel - gray brn. tan w/sand mica layers of loosely cemented sand & gravel. Large cobbles & cemented gravel.
33	27adb	Fairview Farms Inc. Well # 5	1940	D,I,Mn	275	400	35	53 - 61 65 - 75 195 - 220 240 - 263	Irrigation of 110 acres.
34	27ad	Fairview Farms Inc. Well # 2	1939	D,I,Mn	408	200	30	66 - 83	Irrigation of 2 acres.
35	27addc	Fairview Farms Inc. Well # 1	1954	D,I,Mn	182	100	NA	139 - 150	Gravel at 137 - 150' bgs.
36	27dc	(b) (6)	May 1971	D	72	20	10	None, Cased to 67' bgs.	Sand and gravel, occ. boulders - TGA aquifer.
37	27bd	(b) (6)	1939	I, Dairy	60	150	25	perf. Zone depth = ?	Sandy loam, sand rock, gravel
38	27dacc	Wood Village Well # 3	1980	M	300	700-800	78	200-230 245-255 270 - 280	Sand & gravel; Sand & gravel; & Gray claystone.
	Reynolds Metals Company (RMC) Production Wells								
PW-01	23bdda	RMC Well # 01	1942	P	282	750	85	265 - 277	Loose gravel & conglomerate
PW-02	23acca	RMC Well # 02	1942	P	268	400	78	251 - 263	Very loose gravel & sandy gravel
PW-03	23acda	RMC Well # 03	1942	P	281	NA	72	253 - 264	Gravel & coarse gray sand
PW-04	23adca	RMC Well # 04	1942	P	190	1300	53	170 - 180	Gravel & coarse sand.
PW-05	23adcb	RMC Well # 05	1943	P	330	NA	60	160 - 180 182 - 187 248 - 253	Cemented gravel & loose sand Loose sand/gravel with clay Tight gravel
PW-06	23adcb	RMC Well # 06	1952	P	279	NA	55	190 - 210 267 - 276	Coarse sand Loose sand with clay

Table 7-1
Wells Located Within 1-Mile Radius of RMC Facility
Reynolds Metals Company
Troutdale, Oregon

Well Inventory No.	Well Location (by 1/4-1/4 Section)	Original Well Owner	Date Completed	Original Well Use (a)	Total Well Depth (ft bgs) (b)	Well Yield (gpm) (c)	Static Water Level from Original Well Report (ft bgs)	Screened or Perforated Interval (ft bgs)	Water-Bearing Material & Comments
PW-07	23adcd	RMC Well # 07	1952	P	254		70	223 - 230	Blue/brown clay
								232 - 246	Loose gravel/sand
PW-08	23adca	RMC Well # 08	1952	P	248		60	158 -174	Loose sand & gravel
								195 - 206	Loose sand & gravel
								210 - 218	Loose & cemented sand/gravel
								235 - 242	Sand & silt
PW-09	23acdc	RMC Well # 09	1949	P	180		105	155 - 180	Gray sand
PW-10	23acdc	RMC Well #10	1955	P	625	1,100	78	144 - 185	
								440 - 482	Sandy clay & gravel
								522 - 530	Sand & gravel
								538 - 558	Sand & gravel
PW-11	23acdd	RMC Well #11	1955	P	592	1,500	45	150 - 163	
								417 - 434	Sand & gravel at both zones.
								502 - 533	
PW-12	23dbab	RMC Well #12	1954	P	584	1,475	39	147 - 187	Coarse sand
								512 - 518	Loose sand & gravel at next 4 perforated
								522 - 538	zones.
								544 - 555	
								563 - 578	
PW-13	23dbad	RMC Well # 13	1949	P	195	1,200	105	143 - 190	Coarse sand, some small gravel. Location approximate.
PW-14	23dbad	RMC Well # 14	1949	P	644		49	150 - 189	
PW-15	23daba	RMC Well # 15	1953	P	275	1,350	41	255 - 273	Sand & gravel. Decommissioned in February 1995.

Table 7-1
Wells Located Within 1-Mile Radius of RMC Facility
Reynolds Metals Company
Troutdale, Oregon

Well Inventory No.	Well Location (by 1/4-1/4 Section)	Original Well Owner	Date Completed	Original Well Use (a)	Total Well Depth (ft bgs) (b)	Well Yield (gpm) (c)	Static Water Level from Original Well Report (ft bgs)	Screened or Perforated Interval (ft bgs)	Water-Bearing Material & Comments
PW-16	23bdca	RMC Well # 16	1967	P	279	545	16	151 - 192	Sand with some gravel
								256 - 269	Sand, silt & gravel
PW-17	23caad	RMC Well # 17	1969	P	310	1,090	20	170 - 207	Sand & fine gravel
								221 -238	Sand, some gravel
								280 - 300	Sand, some gravel
PW-18	23dabc	RMC Well # 18	1970	P	300	1,090	15.75 *	148 - 189	Sand
								229 - 260	Sand & gravel

NOTES:
1. Well log information compiled from original Water Well Report forms collected from Oregon Water Resources Department, Salem, Oregon. Also literature review from McCarthy and Anderson, 1990.
2. Refer to Figure 7-1 for approximate well locations and Appendix E for well logs.

(a) **Original Well Use:**

D = Domestic M = Municipal P = Production Wells

I = Irrigation Mn = Manufacturing T = Test

(b) ft bgs = feet below ground surface.

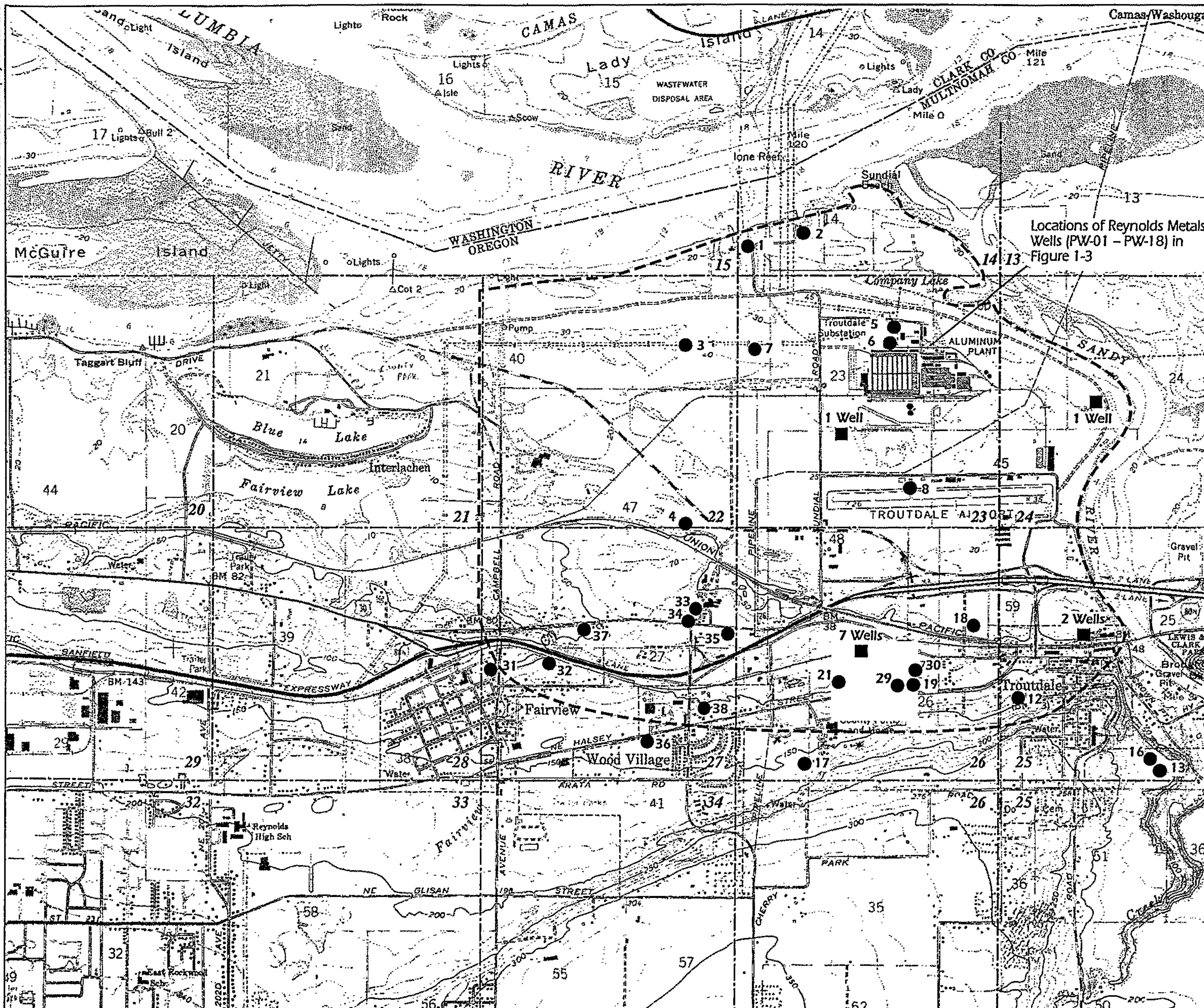
(c) Well yield reported in gallons per minute.

Yield value from pumping (air test, boiler test, etc.) test rate performed after well completion.

NA = Information not available.

* Static Water level for February 2, 1995.

107493.D4.08 RMC ConceptHydro Model 2/96



LEGEND

21 ● Well identified by Oregon Water Resources Department (WRD). Water wells located within a 1-mile radius of site (Table 7-1, Appendix D). Wells located to the nearest 1/4–1/4 section.

7 Wells ■ Number of wells in this section identified by WRD water well reports and potentially located within 1-mile radius of site (Table 7-1, Appendix D).

— — — — Approximate 1-mile radius around industrial site boundary, Columbia River to the north, and Sandy River to the east.

Notes:

1. Wells identified outside the 1-mile radius are used for hydrogeologic cross section information. Oregon WRD well reports are provided in Appendix D.
2. Rivers are assumed to be boundaries to groundwater flow.

Base map: U.S. Geological Survey 7.5 minute Camas, Washington Quadrangle. Photo revised 1970 and 1975. Contour interval: 10 feet.

NORTH

0 — 2,000 Feet
Approximate Scale

Figure 7-1
LOCAL WATER USE SURVEY
WELL LOCATION MAP
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
CONCEPTUAL HYDROGEOLOGIC MODEL REPORT

CH2M HILL

the City of Troutdale water distribution system and that the well is inactive and may have been abandoned, although no abandonment log was on file at OWRD (Young, 1995). Young also reported that water from this well was of poor quality, "or bad tasting." Another well that is screened within deeper sediments is RMC production well PW10, as discussed in Section 6. Groundwater from this well, screened within deeper SGA sediments, is reported to contain slightly elevated concentrations of chloride that may be associated with deeper marine sedimentary rocks.

Two wells (WIN 5 and 6) are located at the BPA Troutdale Substation adjacent to the north side of the plant. BPA staff indicate that WIN 5 well is not used because of historically low yield conditions. Because of elevated hydrogen sulfide concentrations, groundwater from WIN 6 is not used for potable water; bottled water is supplied for the seven or eight substation employees (Purchase, July 1995). The yield at WIN 6 is estimated at about 300 gallons per day (Sherer, 1995).

Two other wells are potentially located downgradient and northwest of the RMC facility: an industrial well at Sundial Marine Tug and Barge (WIN 1) and a domestic well (currently not used for potable water) at Gresham Sand and Gravel (WIN 2).

As previously discussed (see Section 1), RMC owns several deep production wells at its Troutdale facility (Figure 1-3). In addition to industrial use, groundwater from these wells also provides drinking water to RMC employees (CH2M HILL, 1995a).

The higher yield municipal wells owned by the City of Troutdale (WIN 12), City of Fairview (WIN 31 and 32), and Wood Village (WIN 38) are located upgradient, southeast of the RMC site and cross-gradient, southwest of the RMC site (Figure 7-1).

Locations for several wells were not identified because of poor location-specific documentation on the water well report forms. These wells are identified on Figure 7-1 and Table 7-1.

7.1 Water Rights Survey

Surface water use permit data were requested from OWRD for the following surface water locations:

- Sandy River from Interstate Highway 84 (south) to the confluence with the Columbia River (north)
- Columbia River from river mile 120.5 (east) to river mile 101 (west), which is the confluence with the Willamette River

Because the Columbia River spans the state boundary, surface water permit data were obtained from both Washington and Oregon. The sources of water rights information were:

- Oregon Water Resources Department, Water Rights Department, Salem, Oregon

- Washington Department of Ecology, Shorelands and Water Resources Program Department, Spokane and Lacey, Washington

In addition, groundwater use permits were requested for T1N, R3E, Sections 14, 15, 22, 23, 24, 25, 26, and 27. Table 7-2 presents a summary of the surface water use permits and Table 7-3 shows the groundwater use permit findings for the site vicinity.

7.1.1 Surface Water

OWRD did not have on file any surface water permit data for point of diversions from the Sandy River for the requested area.

Seventeen surface water permits were identified for the area along the Columbia River downstream and immediately upstream of the RMC facility (Table 7-3).

7.1.2 Groundwater

A total of 21 groundwater use permits were identified for the site area. Available groundwater permit data for T1N, R3E, Sections 14, 15, 22, 23, and 24 are presented in Table 7-2. Groundwater permit data are also available for sections 25 through 28 but are not presented here because these locations are considered to be upgradient of the RMC facility. RMC owns 20 of these permitted wells and the other permit owner is BPA, as identified in Section 6 (WIN 5 in Table 7-1).

Table 7-2
Groundwater Permit Data Summary
Reynolds Metals Company
Troutdale, Oregon

Well Inventory Number *(a)*	Owner or Agency	Permit No.	Priority Date	1/4-1/4 Section	Original Use *(b)*	Category *(c)*	Rate (gpm)	P/A *(d)*	Legal Description
T1N, R3E, Section 22									
3	Fairview Farms Well # 6	GR 1589	12/31/50	SENE	ID / IM	3 / 4	1,200	P/A	3,000 ft., N. from cor, Sec 22, 23, 26 & 27
T1N, R3E, Section 23									
PW-01	Reynolds Metals Co.	GR 445	2/28/42	SENW	IM	4	750	P	No 37.09 ft., W. 27.32 ft., from common cor, Sec 23 - 26
PW-02	Reynolds Metals Co.	GR 445	1/31/42	SWNE	IM	4	530	P	No 37.49 ft., W. 19.50 ft., from common cor, Sec 23 - 26.
PW-03	Reynolds Metals Co.	GR 445	2/28/42	SWNE	IM	4	600	P	No 36.74 ft., W. 15.34 ft., from common cor, Sec 23 - 26.
PW-04	Reynolds Metals Co.	GR 445	6/30/42	SENE	IM	4	1,040	P	No 35.40 ft., W. 9.67 ft., from common cor, Sec 23 - 26.
PW-05	Reynolds Metals Co.	GR 445	2/28/43	SENE	IM	4	1,900	P	No 37.40 ft., W. 10.15 ft., from common cor, Sec 23 - 26.
PW-06	Reynolds Metals Co.	GR 445	12/31/47	SENE	IM	4	1,070	P	No 35.59 ft., W. 11.57 ft., from common cor, Sec 23 - 26.
PW-07	Reynolds Metals Co.	GR 445	2/28/45	SENE	IM	4	1,000	P	No 34.04 ft., W. 9.47 ft., from common cor, Sec 23 - 26.
PW-08	Reynolds Metals Co.	GR 445	5/31/48	SENE	IM	4	1,010	P	No 35.81 ft., W. 8.04 ft., from common cor, Sec 23 - 26.
PW-09	Reynolds Metals Co,	GR 445	5/31/49	SWNE	IM	4	100	P	No 34.59 ft., W. 17.44 ft., from common cor, Sec 23 - 26.
PW-10	Reynolds Metals Co.	GR 445	7/31/49	SWNE	IM	4	1,180	P	No 31.98 ft., W. 17.54 ft., from common cor, Sec 23 - 26.
PW-11	Reynolds Metals Co.	GR 445	7/31/49	SWNE	IM	4	1,120	P	No 32.46 ft., W. 14.74 ft., from common cor, Sec 23 - 26.
PW-12	Reynolds Metals Co.	GR 445	7/31/49	SWNE	IM	4	1,240	P	No 29.44 ft., W. 17.19 ft., from common cor, Sec 23 - 26.
PW-13	Reynolds Metals Co.	GR 445	8/31/49	SWNE	IM	4	450	P	No 28.39 ft., W. 15.34 ft., from common cor, Sec 23 - 26.
PW-14	Reynolds Metals Co.	GR 445	8/31/49	SWNE	IM	4	1,050	P	No 28.39 ft., W. 13.34 ft., from common cor, Sec 23 - 26.
PW-15	Reynolds Metals Co.	GR 445	1/15/53	SENE	IM	4	1,200	P	No 29.64 ft., W. 6.54 ft., from common cor, Sec 23 - 26.
PW-16	Reynolds Metals Co.	G 3453	12/27/66	SENW	IM	4	1,032	P	1,930 ft W. & 1,700 ft N. fm SW cor, dlc 60
PW-17	Reynolds Metals Co.	G 4510	7/2/69	NESW	IM	4	1,032	P	580 ft N. & 1,350 ft W. fm SW cor, dlc 60
PW-18	Reynolds Metals Co.	G 4786	1/9/70	NESE	IM	4	848	P	540 ft N. & 442 ft E fm SW cor, calvin reed dlc 60
7	Fairview Farms Well # 4	GR 1587	12/31/43	SWNW	IM / ID	4 / 3	700	A / P	2,300 ft., N. from cor, sec 22, 23, 26 & 27
5	BPA Well # 1	GR 3796	1/31/47	NWNE	IM	4	440	P	No 27 degrees 34 min., 10 sec.W. 4,642 ft., from SE cor, Sec 23.

Notes:

*Source: **Oregon Water Resources Department,** Salem Oregon: E-Mailed on 7/27/95 by Bob DeVyldere.*

(a) Refer to Table 7-1 for corresponding Well Inventory Number.
Groundwater use permits are not required for single or group domestic use wells or yields of less than 15,000 gallons per day.
(b) Original Use: IM = Manufacturing; ID = Domestic
(c) Category: 3 = Irrigation: 4 = Industrial Use
(d) P/A: P = Primary Source; A = Alternate Source

gpm = gallons per minute
BPA = Bonneville Power Administration

Table 7-3
Surface Water Diversion Permit Data Summary for Oregon and Washington
Reynolds Metals Company
Troutdale, Oregon

Surface Water No.	Surface Water POD Location	Agency or Owner Name (a) (b)	Permit No. or Control No.	Priority Date	Section	1/4-1/4 Section	Original Use (c)	Rate (cfs)	P/A (d)	Legal Description / Comments
Columbia River Point of Diversions in Oregon *(a)*										
		T1N, R2E								
1	Columbia R 2	Port of Portland	S 51547	11/18/92	6	SENW	WI / MU *(e)*	51.0	A	3,400 ft N. & 2,080 ft E. from NW cor, Sec 6. For Portland International Airport & Cntr. Approx. River Mile (RM) = 109.8.
2	Columbia R 1	Port of Portland	S 51547	11/18/92	10	SWSW	WI / MU *(e)*	51.0	P	1,000 ft N. & 800 ft E. from SW cor, Sec 10. For Portland International Airport & Cntr.
3	Columbia R 1	Port of Portland	S 50680	6/22/88	11	NWSW	IR	2.1	P	2,410 ft N. and 4,710 ft W. from SE cor, sec 11.
4	Columbia R 1	Port of Portland	S 50680	6/22/88	13	SWNW	IR	2.1	P	424 ft So. & 337 ft E. from meander cor, sec 13-14.
		T1N, R3E								
5	Columbia R	Mult. Co. Park Service District	S 50861	5/25/89	21	NENE	IR	0.15	P	500 ft S. & 500 ft west from NE cor, sec 2. Approx. RM = 118.7.
		T2N, R1W								
6	Columbia R 3	Port of Portland	S 51547	11/18/92	24	SESE	MU / WI *(e)*	51.0	A	800 ft N. & 200 ft west from se cor, sec 24. For Rivergate Industrial District. Loc. at So. bank of No. Portland Harbor, Vancouver 7.5-min. Quad. South of Vancouver Lake on Oregon Side of Columbia R. Near RM = 103. Aluminum Plant on No. Side Columbia River.
		Local Streams or Springs in Site Proximity								
7	A Spring	Miller Paint Co.	S 50240	11/17/87	23	NENW	IM	0.09	P	1,061 ft S. & 1,834 ft E. from NW cor., sec 23
Columbia River Point of Diversions in Washington *(b)*										
		T1N, R3E								
8	Columbia R.	Smith Bros.	S2*06702C 3039	10/3/45	7		C/In	2.0	--	Hutson Martin DLC, old Appl. No. = 06702 Used for washing gravel.
9	Camas Slough	Crown Willamette In.	S2*00891C 0056	3/5/23	11	$NE^{1/4}SE^{1/4}$	C/In FP	45.0 45.0	-- --	Lot 2? Old appl. No. = 00891.
10	Camas Slough	Crown Willamette P.	S2*03060C 0465	7/28/30	11	$SE^{1/4}$	C/In	50.0	--	Lot 2? Old Appl. No. = 03060.
11	Camas Slough	Crown Zellerbach	S2*08040C 3123	9/27/47	11	$SE^{1/4}$	C/In	25.0	--	Lot 2? Old Appl. No. = 08040.
12	Columbia R.	Nevin, Dr. Robert B.	S2-27364C	6/16/88	13 (baa)	$NE^{1/4}NE^{1/4}NW^{1/4}$	IR	0.04	--	Appropriation for May 1 - Oct. 1 for Annual QA = 1.0 acre-ft/yr.

Table 7-3
Surface Water Diversion Permit Data Summary for Oregon and Washington
Reynolds Metals Company
Troutdale, Oregon

Surface Water No.	Surface Water POD Location	Agency or Owner Name (a) (b)	Permit No. or Control No.	Priority Date	Section	1/4-1/4 Section	Original Use (c)	Rate (cfs)	P/A (d)	Legal Description / Comments
		T1N, R4E								
13	Columbia R.	Sampson R R ET UX	S2*11896C 5951	12/15/52	24	$SE^{1/4}NW^{1/4}$	IR	2.5	--	**Max. No. of irrigated acres** = 220.0. Old Appl. No. = 14523.
		T2N, R1E								
14	Columbia R.	Boise Cacade Corp.	S2*20937C 10749	5/3/68	27	TR-24	C/In	0.5	--	TR-24. Old Appl. No. = 20937. POD location: 1,058 ft E. & 1,854 ft from west qtr corner of Sec 27. **Annual QA** = 360.0 acre-ft/yr.
15	Columbia R.	Willamette HI-GRAD. VA. Barracks US Res	S2-20214C	5/11/72	34		C/In	0.21	--	**Annual QA** = 9.0 acre-ft/yr. POD location: 90 ft S. & 50 ft E. from the North qtr corner of Sec 34.
16	Columbia R.	Port of Vancouver	S2-25833C	3/11/81	12	$S^{1/2}SW^{1/4}$	Rec. & Beautification	300.0	--	non-consumptive use.
		T4N, R1W								
17	Columbia R. (Bach. Slough)	Bachelor IS Ranch	S2*21970CGBB 11713	1/9/70	14	GL-3	IR	5.93	--	Annual QA = 1,290.0 acre-ft/yr. for max. no. of acres = 750. Time of use: 5/1-10-31. Old Appl. No. = 21970G Multiple PODs.

Notes:

(a) Information from ***Oregon Water Resources Dept***., Salem Oregon - original permit application.
(b) Information from **Washington Department of Ecology**, Spokane, WA.
(c) Original Use:

WI = Wildlife
MU = Municipal
IR = Irrigation
C = commercial
In = Industrial
FP = Fire protection

QA = the authorized total annual diversions for specified use (for WA. permit info.)

(d) P/A: P = Primary Source; **A** = Alternate Source
(e) Original **Water Use** and **Rate Data** may have been combined.
cfs = cubic feet per second.

SECTION 8

REFERENCES

References

Bet, James N., and Malia L. Rosner (Landau Associates, Inc.). May 1993. "Geology near Blue Lake County Park, Eastern Multnomah County, Oregon." *Oregon Geology.* Volume 55. 11 pp.

Bouwer, H., and R. C. Rice. 1976. A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers with Completely or Partially Penetrating Wells. *Water Resources Research.* Vol. 12. No. 3: 423.

_______ . 1989. "The Bouwer and Rice Slug Test–An Update." *Ground Water.* 27 (3): 304–309.

Cassidy, Dick (U.S. Army Corps of Engineers Hydrologist). July 1995. Personal communication.

CH2M HILL, 1995a. *Removal Site Assessment Report.* January 1995.

__________ , 1995b. *Quarterly Groundwater Monitoring Report No. 1.* January 9, 1995.

__________ , 1995c. *Quarterly Groundwater Monitoring Report No. 2.* April 13, 1995.

__________ , 1995d. *Quarterly Groundwater Monitoring Report No. 3.* June 1995.

__________ , 1995e. *Annual Groundwater Monitoring Report: August 1994–August 1995.* November 1995.

Cooper, H.H., and C.E. Jacob, 1946. "A Generalized Graphical Method for Evaluating Formation Constants a Summarizing Well Field History." *American Geophysical Union Transcripts.* Vol. 27: 526–534.

County Assessor's Office, Portland, Oregon. August 1995. Personal communication.

Ecology and Environment, Inc. October 1991. *Site Inspection Report for Swift Adhesives.*

Erskine, A.D., 1991. "The Effect of Tidal Fluctuations on a Coastal Aquifer in the UK." *Ground Water.* Vol. 29, No. 4: 556-562.

Geraghty & Miller, Inc. 1989. *AQTESOLV, Aquifer Test Solver Version 1.00 Documentation.* 135 pp.

Hantush, M.S., 1960. "Modification of the Theory of Leaky Aquifers." *Journal of Geophysical Research.* Vol. 65, No. 11: 3,713–3,725.

______________. 1961a. "Drawdown Around a Partially Penetrating Well." *Journal of the Hydrology Division, Proceedings of the American Society of Civil Engineers.* Vol. 87, No. HY4: 83–98.

________________. 1961b. "Aquifer Tests on Partially Penetrating Wells." *Journal of the Hydrology Division, Proceedings of the American Society of Civil Engineers.* Vol. 87, No. HY5: 171–194.

Hantush, M.S., and C.E. Jacob, 1955. "Non-steady Radial flow in an Infinite Leaky Aquifer." *American Geophysical Union Transcripts.* Vol. 36: 95–100.

Hartford, S. V., and McFarland, W. D., 1989. *Lithology, Thickness, and Extent of Hydrogeological Units Underlying the East Portland Area, Oregon.* U.S. Geological Survey Water Resources Investigations Report 88-4110. 23 p., 6 sheets.

Hoffstetter, W. H., 1984. "Geology of the Portland Well Field." *Geological Society of America Bulletin.* Vol. 49: 831–930.

Hogenson, G. M., and B. L. Foxworthy. 1965. *Ground Water in the East Portland Area.* U.S. Geological Survey Water Supply Paper 1793. 78 p., p. 63–67.

McCarthy, K. A., and D. B. Anderson. 1990. *Ground-Water Data for the Portland Basin, Oregon and Washington.* U.S. Geological Survey Open File Report 90-126. 55 p.

National Oceanic and Atmospheric Administration and U.S. Department of Commerce. 1974. *Climates of the States*, Volume 2 (Western States). New York.

Oregon Water Resources Department, Salem, Oregon. July 1995. *Administrative Rules for Construction, Maintenance and Abandonment of Monitoring Wells and Other Holes in Oregon. Chapter 690, Division 240.*

_______. January 1994. *Administrative Rules for Water Supply Well Construction and Maintenance. Chapter 690, Division 200.*

Papadopulos, I.S., and H.H. Cooper, 1976. "Drawdown in a Well of Large Diameter." *Water Resources Research.* Vol. 3: 241–244.

Parametrix, Inc. June 1991. *East Multnomah County Database and Model, Draft Geologic Interpretation Detailed Study Area Volume II Hydrogeologic Unit Thickness and Elevation Maps.* Prepared for Oregon Department of Environmental Quality.

Piper, A. M., 1944. "A Graphical Procedure in the Geochemical Interpretation of Water Analyses." *Am Geophys. Union Trans.* Vol. 25: 914–923.

Purchase, Larry (Bonneville Power Administration, Environmental Fish and Wildlife). July 1995. Personal communication.

Serfes, M.E., 1991. "Determining the Mean Hydraulic Gradient of Ground Water Affected by Tidal Fluctuations." *Ground Water.* Vol. 29, No. 4: 549-555.

Sherer, Brett (Bonneville Power Administration). July 13, 1995. Personal communication.

Stiff, H. A., Jr., 1951. "The Interpretation of Chemical Water Analysis by Means of Patterns." *Journal of Petroleum Technology.* Vol. 3., No. 10: 15–17.

Swanson, R. D., W. D. McFarland, J. B. Gonthier, and J. M. Wilkinson. 1993. *A Description of Hydrogeologic Units in the Portland Basin, Oregon and Washington.* U.S. Geological Survey Water Resources Investigation Report 90-4196.

Theis, C.V. 1935. "The Relation Between the Lowering of the Piezometric Surface and the Rate and Duration of Discharge in a Well Using Groundwater Storage." *American Geophysical Union Transcripts.* Vol. 16: 519–524.

Walton, William C. 1970. *Groundwater Resource Evaluation.* McGraw-Hill Book Company. New York, New York.

Washington Department of Ecology. September 1995. Linda Kiefer, Shorelands and Water Resources Program Department. Personal communication. Spokane, Washington.

Willis, R. F., 1977. *Ground Water Exploratory Program.* Bureau of Water Works, Portland, Oregon. 284 p., 17 plates.

_________ 1978. *Pilot Well Study.* Bureau of Water Works, Portland, Oregon. 150 p., 23 plates.

Young, Bob (Port of Portland, Troutdale Airport lead maintenance staff). July 21, 1995. Personal communication.